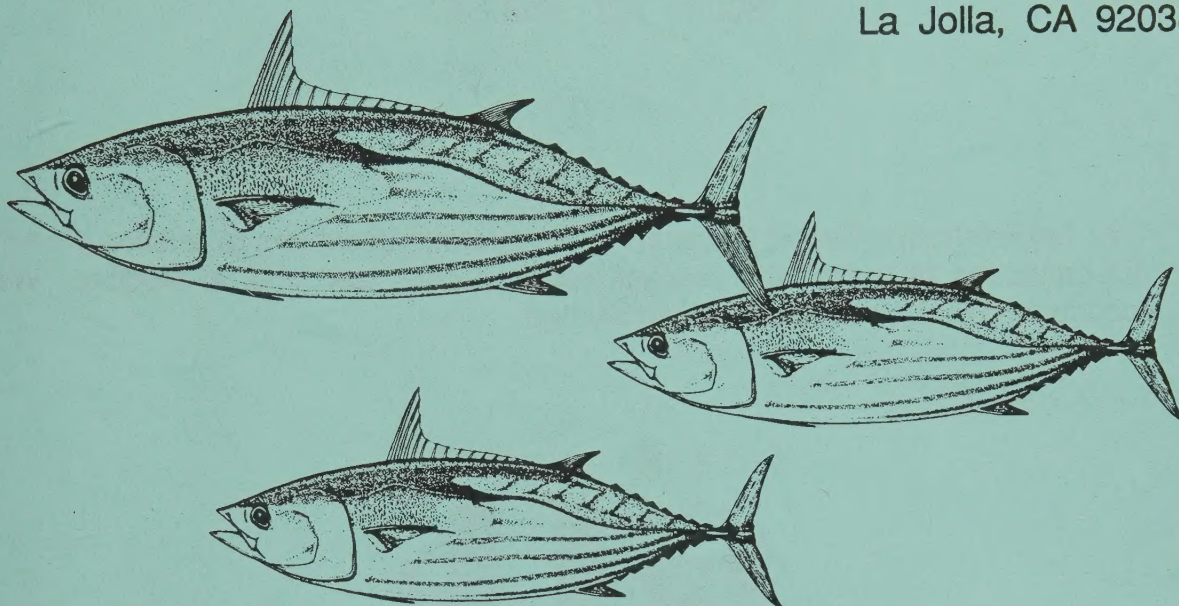


National Marine Fisheries Service
Southwest Fisheries Center
P.O. Box 271
La Jolla, CA 92038



Director's Report
to the
41st
Tuna Conference

On Tuna & Tuna-Related Activities
at the Southwest Fisheries Center
for the Period May 1, 1989
to April 30, 1990

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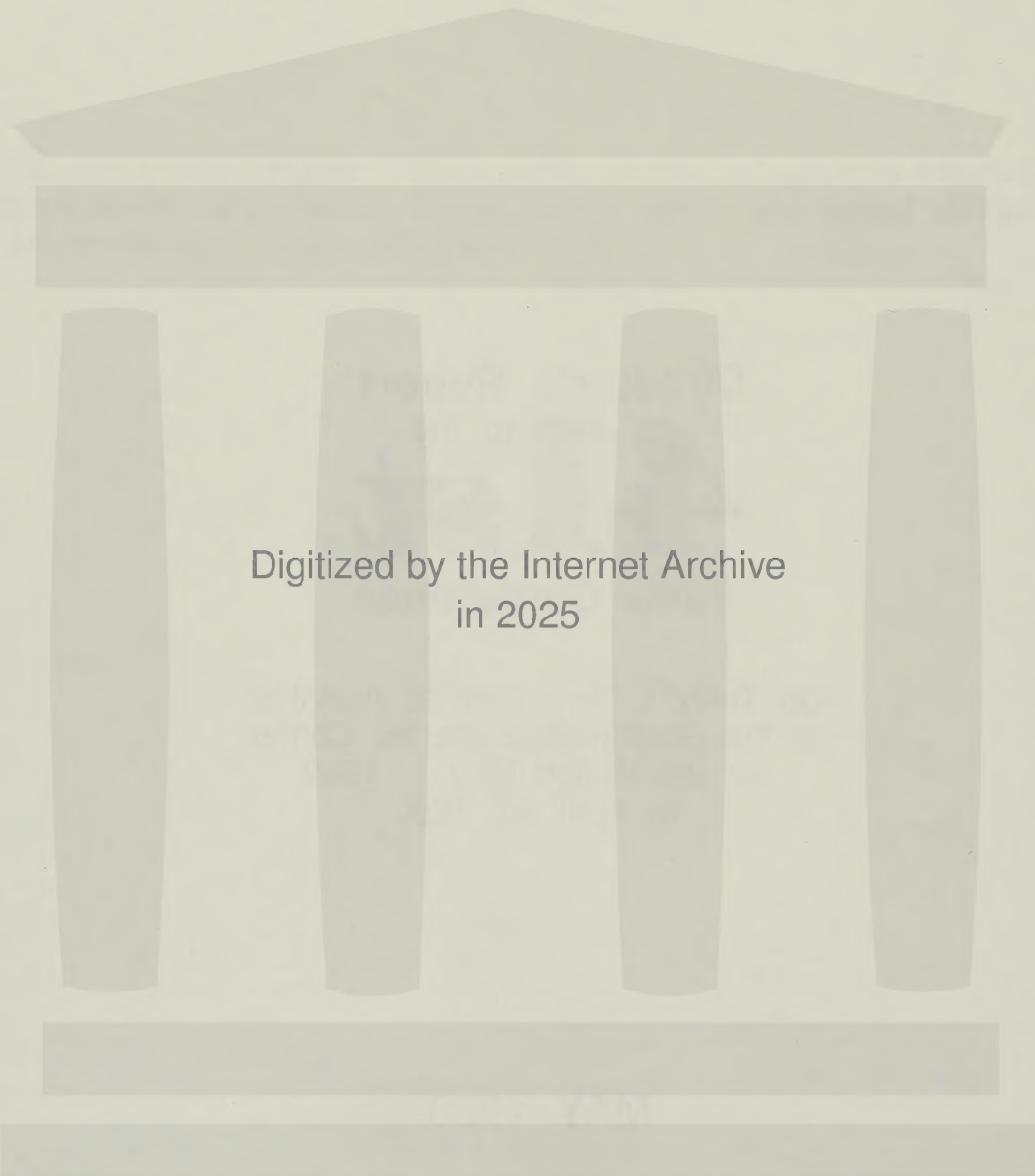
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TABLE OF CONTENTS

I. EXECUTIVE SUMMARY	1
II. ECONOMIC OVERVIEWS	5
- Trends in Worldwide Tuna Production and Trade	5
- Statistics Reviewed on the U.S. Canned Tuna Industry for 1988	5
- First Three Quarters 1989 Statistics of U.S. Canned Tuna Industry Compiled	6
III. INDIAN OCEAN FISHERIES	7
- Review of Indian Ocean Fisheries Completed	7
- Update on the Seychelles Purse Seine Fishery	7
IV. PACIFIC OCEAN FISHERIES	9
Pacific Albacore	9
- Summary Completed of 1988 North and South Pacific Albacore Data	9
- Long Term Decline Noted in West Coast Albacore Catch Rates	9
- North Pacific Albacore Workshop Held	9
- North Pacific Albacore: Stock Structure and Size Composition	10
- International North Pacific Albacore Conservation (INPAC) Initiative	10
- Bartoo Travels to Japan to Discuss Scientific Cooperation on Albacore	11
- Impacts of North Pacific High-Seas Driftnet Fishing: Recent Scientific Negotiations	11
- Summary of the 1989 U.S. Albacore Season	12
- SPAR Workshop Held in Fiji in June	13
Hawaii's Fisheries	13
- Hawaii Midyear Fishery Reports	13
- Hawaii Longline, Handline and Troll Tuna and Pelagic Landings	14
- Hawaii Samples Collected for Northeast Fisheries Science Center	14

South Pacific Tuna Fisheries	14
- NMFS Participates in Planning Meeting of Forum Fisheries Agency	14
- User Manuals and Documentation Completed for Annual Report Preparation	15
- Logbook Data Base Archiving	15
Tuna Behavior and Physiology Studies	16
- Research on "Burnt Tuna" Progressing	16
- Manuscript on Swimming Physiology of Tunas Completed	17
Pacific Billfish Programs	17
- Pacific Blue Marlin Tracked Successfully	17
- Pacific Cooperative Marine Game Fish Tagging	18
- Eastern Pacific Striped Marlin Fishery Reviewed	18
- 1988 Pacific International Billfish Angler Survey Results	19
- Squire Receives Award	20
 V. RESEARCH IN SUPPORT OF THE 1972 MARINE MAMMAL PROTECTION ACT	 21
- Introduction	21
- Voluntary 'Dolphin-Safe' Tuna Policy Announced	21
- SWFC Participates in NAS Committee on Dolphin-Safe Alternative Fishing Methods to Purse Seining	22
- Effects of Dolphin Group, Percent Coverage, and Fleet Size on Estimates of Dolphin Mortality Derived From Tuna Vessel Observer Data	22
- Chartering a Fishing Fleet: Is It a Worthwhile Assessment Strategy?	23
- Monitoring Trends in Dolphin Abundance in the Eastern Tropical Pacific Using Research Vessels Over a Long Sampling Period: Analyses of First Three Years	24
- Tuna/Dolphin Data Bases Updated	25
- Summary of 1987 Tuna/Porpoise Observer Data Published	25
- Dolphin Stock Assessment Cruises for 1989 Completed	26
- Life History Parameters of ETP Dolphin Species Examined as Potential indices of Population Condition	27
- Eastern Tropical Pacific Cetacean Habitat Studies: Species Distributions and Habitat Variability	28
- Studies and Workshop on Effects of Seal Bombs Used in the Yellowfin Tuna Purse Seine Fishery Completed	28

- Impacts of Changes in Dolphin Data Gathering Requirements are Examined	29
- Research Plan Integrates Division Studies of Population Regulation in Eastern Tropical Pacific Dolphins	30
VI. MISCELLANEOUS	33
- Computer Graphics for Evaluation of the Pacific Tuna Fisheries Developed	33
- Fishing Industry Reviews Proposed Seafood Regulations	33
- SWFC Scientists Attend FAO Planning Meeting	34
- Brill Attends Two International Conferences	34
- Tuna Vessel Observers Start Collecting Turtle Data	35
- Studies on Species Associated with Yellowfin Tuna in the Eastern Tropical Pacific	35
VII. SWFC PUBLICATIONS ON TUNA AND TUNA-RELATED SUBJECTS	37

I. EXECUTIVE SUMMARY

This report describes tuna-related research activities at the Southwest Fisheries Center (SWFC) over the past year. Work was carried out at Center headquarters at the La Jolla Laboratory in La Jolla, California; at the Center's Honolulu Laboratory in Honolulu, Hawaii, and at the Pacific Fisheries Environmental Group in Monterey, California. This document is not intended as a comprehensive account of our work on tuna and tuna-related subjects, but rather as an informal statement of major activities and events. It was compiled and edited by Susan Smith and Lorraine Prescott.

The following summary provides some of the highlights of these activities.

Albacore

In 1989, considerable attention was given to developments in albacore fisheries of the Pacific, which emerged just prior to and during the May 1989 meeting of the Eleventh North Pacific Albacore Workshop held in La Jolla last May, and at the second meeting of the South Pacific Albacore Research (SPAR) group, held in Fiji in June. Tuna researchers with Gary Sakagawa's **Pelagic Fisheries Resources Division** in La Jolla, and Jerry Wetherall's **Pelagic Resources Investigation** in Hawaii were particularly occupied with albacore issues this past year.

New analyses and data presented at the North Pacific Albacore Workshop indicated that the condition of the North Pacific albacore stock was much poorer than previously believed. A combination of declining catch-per-unit of effort (CPUE), increased effort in fisheries that harvest young fish, unknown but possibly high incidental mortalities of very small fish by the squid driftnet fishery, and apparently missing or much-decreased year-classes, all suggested serious problems in recruitment of fish to the fishery.

An Albacore Management Information Document, compiled by the SWFC Albacore Task Force (Dick Parrish, chair) was published soon after the May Workshop (NOAA-TM-NMFS-SWFC-126). The document marks completion of work specified in the North Pacific Albacore Plan, which was originally developed in 1983 and revised in 1986. These results will provide a good basis for developing a second stage plan now in the works.

An important offshoot of the Albacore Workshop was the SWFC International North Pacific Albacore Conservation (INPAC) initiative. This is a proposal for monitoring and collecting information on the albacore population to determine reasons for the poor recruitment, and to undertake the study through international cooperation. The first INPAC forum is scheduled for 1991 in Japan. Norm Bartoo, head of the **Stock Assessment and Fishery Impact Analysis Program** within La Jolla's Pelagic Fisheries Resources Division, is U.S. coordinator for the INPAC Program, and recently returned from Japan and a series of successful meetings with Japanese scientists concerning the program and cooperative work.

Also at the La Jolla Laboratory, within the Coastal Fisheries Resources Division, Mike Laurs' **Fisheries Environmental Investigations Program** continues to focus on the distribution, availability, and migration patterns of north Pacific albacore, and on monitoring the U.S. West Coast albacore fishery. Albacore Fish Bulletins were distributed bi-weekly during the West Coast albacore fishing season last year. Predictions of poor recruitment proved true, as 1989 commercial landings ranked with the lowest ever recorded.

At the Honolulu Laboratory, scientists continue to be closely involved with Pacific albacore issues. The program, **Evaluation of Drift Net Impacts on Tunas, Billfishes, and Sea Turtles**, headed by Jerry Wetherall, is devoted entirely to evaluating the high-seas gillnet fisheries targeting on squid and al-

bacore in the North Pacific Transition Zone. The program supports National Marine Fisheries Service (NMFS) policy and management staffs in the Southwest Region (SWR) and Washington, D.C., the Western Regional Fisheries Management Council, and other parties, including the U.S. albacore industry, with concerns about the high seas fisheries. Wetherall also participated in two meetings in Tokyo, Japan, in March 1990, on cooperative monitoring of Japan's North Pacific high-seas driftnet fisheries.

Honolulu's **Pelagic Stock Assessment Program**, also headed by Wetherall, assesses stocks of tunas, with emphasis on albacore in the North and South Pacific. The program uses fishery statistics collected through NMFS monitoring programs and biological data from sea surveys and experiments. A South Pacific Albacore Fishery Information Document was completed in September 1989.

Finally, at the **Pacific Fisheries Environmental Group**, work is near completion on a book that describes a time-space predictive model of the albacore fishery off the western U.S., based on environmental and fisheries data.

Tuna Fishery Data Bases

The Southwest Fisheries Center staff handles extensive and complex fishery data bases from tuna fisheries throughout the globe. At La Jolla, the **Multispecies Data Collection and Evaluation Program**, led by Al Coan, continues the important task of processing tuna-dolphin observer data, tuna fisheries data, and other data collected from field experiments, expeditions, and port sampling. The staff maintains the Atlantic tropical tuna data base and develops and maintains data bases for Pacific Ocean and Indian Ocean tunas and large pelagics. They also process data and evaluate the sampling regime for collection of South Pacific Regional Tuna Treaty data. After processing by the SWFC, the information is submitted to the Forum Fisheries Agency (FFA) as required by the Treaty.

This group also provides annual summaries and analyses of fisheries data collected by tuna-dolphin observers for use in marine mammal stock assessments. In 1989, re-enactment of the Marine Mammal Protection Act (MMPA) established a 100% observer

coverage rate for U.S. purse seiners fishing in the eastern tropical Pacific.

Economics and Global Trends in the Industry

In the **Tropical Tuna Fishery Monitoring and Evaluation Program**, led by Gary Sakagawa, the staff monitors tropical tuna trade and fishery developments on a global scale to help interpret and evaluate fishery statistics used to analyze stock condition. Data obtained from international sources are summarized in various publications, including the popular Tuna Newsletter.

The U.S. Tuna Trade Summary for 1988 was completed, which outlines U.S. tuna fleet activity, canned tuna processing, ex-vessel, wholesale and retail prices, fresh tuna markets and imports. This summary is the sixth in a series of comprehensive annual NMFS reviews of the industry.

Other activities continue, such as monitoring U.S. production of tuna for the fresh fish market and various analyses in support of tropical tuna management.

A chapter on eastern tropical Pacific yellowfin tuna fisheries was published for the Tuna and Billfish "blue book", and draft chapters on Pacific swordfish, Indian Ocean yellowfin, and bigeye tunas were also produced. Distribution of chapters was made to all holders of the original volume.

The Tuna Management Information Document by Sakagawa, Bartoo, Herrick, Mackett, McInnis, Parks, Parrish and Wetherall is being finalized at the time of this writing. It describes predicted trends in tuna policy, production, trade, global fisheries, stock abundance, management and research.

Billfish

Within the **Stock Assessment & Fishery Impact Analyses Program** a review of the eastern Pacific striped marlin fishery was

completed and will be included in the Tuna and Billfish "blue book."

The Billfish Newsletter, which gives results of the Pacific International Billfish Angler Survey and Cooperative Marine Game Fish Tagging Program, was distributed in April. Editor of the Newsletter, James L. Squire, Jr., last year was honored with the Billfish Foundation's 1989 Conservation Award for Individual Scientific Achievement.

Two Pacific blue marlin were successfully tracked with ultrasonic transmitters in Hawaiian waters by SWFC biologists with the Honolulu Laboratory.

Mathematical Modeling for Stock Assessment

The **Pelagic Ecosystem Modeling Program**, headed by Pierre Kleiber, continues to evaluate mathematical modeling techniques used in stock assessments, examining them for accuracy and relevancy to management of tuna and related fisheries. The staff also assists in designing and conducting stock assessments and planning sampling projects. Kleiber and Christina Perrin were instrumental in uncovering the discrepancy in the model used to calculate CPUE for the U.S. North Pacific albacore fishery.

ETP Dolphin Research

Within the Fishery-Marine Mammal Interaction Division, led by Douglas DeMaster, scientists with the **Fishery Independent Assessment Program** conduct annual dolphin surveys in the eastern tropical Pacific (ETP) to determine trends in dolphin populations affected by the ETP tuna purse seine fishery, as mandated by the Marine Mammal Protection Act (MMPA). A report was completed in February 1990 on the first 3 years of porpoise monitoring cruises and will be presented at the upcoming International Whaling Commission meetings (June 1990). The report covers analyses and results of the 1986, 1987, and 1988 cruises. Tim Gerrodette is currently the Chief Scientist for the research vessel monitoring program.

Another index to changes in the relative abundance of dolphin populations is being investigated by biologists with the **Fishery Dependent Assessment Program**, led by Steve Reilly. Within this program, Paul Fiedler heads a group that is examining dolphin encounter rates aboard tuna vessels and research vessels in relation to environmental features that may affect dolphin distributions. Currently they are summarizing the influence of environmental variability on the distribution of dolphins. Environmental data are being used to describe 'habitat' for each of the four primary species of dolphin being studied. Also in this program, Elizabeth Edwards leads a group that is working with the Inter-American Tropical Tuna Commission (IATTC) in evaluating the utility of sightings data from tuna vessels for detecting trends in relative abundance of dolphin stocks. Last year, Elizabeth Edwards and Pierre Kleiber won the Department of Commerce Bronze medal for their work on developing a computer graphics software program, the Tuna Observer-Porpoise Simulation (TOPS) model, which is very useful in identifying bias in catch-per-unit of effort statistics.

The staff of the **Biology Assessment Program**, led by Andrew Dizon, has been studying how trends in life history parameters over time can be used to infer changes in density. Current work deals with how certain reproductive factors respond to various levels of fishing pressure, population size, or forage density in dolphin populations. In addition, this program is responsible for research on stock identification using techniques such as mitochondrial DNA analyses, morphometrics, and acoustics.

Also, in 1989, research work began on the effects on dolphins of explosive devices used to herd the animals during purse seine operations. This work is mandated by a recent Marine Mammal Protection Act amendment. A workshop on the subject was held in November 1989, and a report to the Southwest Region of effects of these devices on ETP dolphins was completed in March 1990.

Hawaiian Tuna Stocks

At the SWFC Honolulu Laboratory, scientists with the **Pelagic Ecosystem Program**, are working with biological and fisheries data on Hawaiian yellowfin, bigeye, and skipjack tuna, and using these data in conjunction with environmental data to model the dynamics of tuna stocks and their habitat. A 5-year research plan for modeling distribution, abundance, behavior, movements, and habitat of tuna around Hawaii was completed in February 1989. The plan served as a working document for informal discussions at the Southwest Fisheries Center, La Jolla Laboratory, in May 1989, on tuna-environment research.

In the **Pelagic Fisheries Management Plan Research Program**, information on basic biological parameters---age and growth, size/cohort composition, mortality rates, reproductive biology and recruitment---is gathered to improve the scientific basis for effective management of billfishes, wahoo, mahimahi and oceanic sharks. Data are collected from the fisheries and from biological experiments.

Other Developments

On February 6, 1990, the House of Representatives passed HR-2061, re-authorizing the Magnuson Fishery Conservation and Management Act (MFCMA) and proposing a number of changes in the Act. One amendment, introduced by Representative

Pat Saiki (R-Hawaii), includes tunas in the MFCMA. As of this writing, the bill is still under consideration in the Senate, where it is sure to prompt further discussion.

On April 12, 1990, H. S. Heinz Co., Bumble Bee Seafoods, and Van Camp Seafoods announced they would only sell tuna that was not taken in association with dolphin. The SWFC Management Team discussed this new development and related SWFC research at recent Center/Region Strategic Planning talks held April 16-18, 1990; however, it is still too early to tell what effect this will have on our research. We plan to continue with the research vessel surveys of dolphin in 1990 and 1991, and the Region plans to continue observing 100% of the certificated vessels that fish in the eastern tropical Pacific.

DR. IZADORE BARRETT
Science and Research Director,
Southwest Region

*May 1990
La Jolla, California*

II. ECONOMIC OVERVIEWS

Trends in Worldwide Tuna Production and Trade

Sam Herrick, industry economist at the La Jolla Laboratory, and Tony Applebaum, student intern from San Diego State University, have completed an analysis of recent trends in global catches of tuna and canned tuna production. They find that worldwide catches of tuna have increased steadily from 2.462 million metric tons (t) in 1979, to 3.418 million t in 1986, an increase of 39% in 8 years. From 1979 to 1985, global production of canned tuna rose from 607,000 t to 703,000 t, an increase of 16%. While these increases in catches and canned tuna production are impressive in themselves, perhaps more striking is the considerable development in the harvesting and canning capabilities of less developed countries relative to that of the historically dominant tuna harvesters and canners, namely Japan, the United States, Spain and France. The rapid development of tuna industries in southeast Asia (Thailand, Indonesia, Philippines, Korea, Taiwan, Malaysia, India, China), Latin America (Mexico, Venezuela, Panama, Brazil), the island nations of the western Pacific, and Africa (Ghana, Ivory Coast) has been largely due to their proximity to abundant tuna resources, relatively low-cost labor sources, strong government backing, and investments from abroad. However, while these are necessary conditions, the impetus for developing tuna industries in these areas relates to a growing worldwide demand for tuna and processed tuna products.

The linear trend model shows global tuna catches increasing at an annual average rate of 5% between 1979 and 1986, with most of this increase due to growth in the fishing operations of developing nations. Growth in the catches by developing nations increased at an annual rate of 6% over the period, from 1.2 million t in 1979 to 1.9 million t in 1986. This compares to an average annual growth rate of 3%, with much more variability, for developed nations, with their catches ranging from 1.3 million t in 1979 to 1.5 million t in 1986. By 1986, developing nations accounted for more

than half of the world's annual tuna catch. The trend model predicts that by 1995 the global tuna catch will reach 4.5 million t (plus/minus 300,000 t). Separate linear forecasts for the developing nations' catch and the developed nations' catch are 2.7 million t (plus/minus 200,000 t) and 1.8 million t (plus/minus 400,000 t), respectively, by 1995.

Globally, canned tuna production grew at an average rate of 3% annually from 1979 through 1985. The rapid development of canned tuna processing capability in developing nations over the period accounts for most of this growth. From 1979 to 1985 canned production by developing nations increased 84%, at an average annual rate of 11% compared to a 5% increase for developed nations, at an average annual rate of 1%. By 1985, developing nations accounted for 22% of the world's annual canned tuna production vis a vis 14% in 1979. The linear trend model for canned tuna predicts global production will reach 900,000 t (plus/minus 200,000 t) by 1995. The developing nations' production is estimated to be 270,000 million t (plus/minus 60,000 t), and production by developed nations is predicted to be 630,000 t (plus/minus 150,000 t) by 1995, based on linear trends estimated for each.

If prevailing trends continue, and assuming that tuna resources can support expanded harvests, global output of raw and processed tuna may increase by as much as 30% by 1995. If recent patterns of growth continue into the future, this expansion is likely to be led by developing nations with burgeoning tuna industries, in which case the tuna industries of the developed nations will continue to face more intense competition, both on the fishing grounds and in the marketplace.

Statistics Reviewed on the U.S. Canned Tuna Industry for 1988

Statistics describing the U.S. canned tuna industry for 1988 were compiled by Wes

Parks, SWFC; Pat Donley, SWR; and Sam Herrick, SWFC, and presented as a feature article in the May 1989 issue of the Region/Center Tuna Newsletter. Data show that the number of active U.S. purse seiners declined to 74 in 1988, continuing the trend begun in 1984. In 1988, 57% of the vessels operated in the eastern Pacific and 43% operated in the western Pacific.

Total receipts of raw tuna by U.S. canneries declined slightly in 1988, but were still well above the recent low of 450,000 short tons (st) of 1985. Total receipts were 510,471 st with imports contributing slightly more than domestic deliveries. Skipjack tuna was the principal species in both domestically-caught and imported receipts. Major foreign suppliers were Taiwan, South Korea, and Ghana. The western Pacific was the major source of albacore and skipjack tuna whereas the eastern Pacific contributed the greatest quantity of yellowfin tuna.

Contract prices for domestically-caught raw tuna delivered to U.S. canneries in American Samoa and Puerto Rico in early 1988 were slightly higher than in late 1987, then declined later in the year to levels below those of 1987. Weighted average exvessel prices paid by cannery for domestically-caught tuna increased for the third straight year to \$1,094 per ton for yellowfin tuna, and to \$977 per ton for skipjack tuna, and were at their highest level since 1982.

U.S. production of canned tuna declined slightly in 1988 reversing the recent increasing trend. U.S. canners packed 31 million standard cases of tuna valued at over \$960 million. U.S. imports of canned tuna reached a record high continuing the increasing trend of recent years. Total imports were 12.5 million standard cases of tuna, valued at over \$298 million. Wholesale list prices in California for canned tuna in early 1988 were at late 1987 levels, but rose slightly by year's end.

First Three Quarters of 1989 Statistics of U.S. Canned Tuna Industry Compiled

Statistics of the U.S. canned tuna industry in the first three quarters of 1989 were compiled by former editor

Wes Parks, Al Jackson (Copy Editor), and Diane Pickelsimer from the Southwest Fisheries Center; and Pat Donley and Mike Thabault of the Southwest Regional Office. A report describing the statistics appeared as articles in the August and November 1989, and February 1990 issue of the SWR/SWFC Tuna Newsletter.

Sixty-three vessels of the U.S. tropical tuna purse seine fleet were at sea at least one day during the first, second and third quarter of 1989, down five vessels from the number active in the first quarter of 1988. Total capacity at sea was down about 8%.

Receipts of all tuna species at U.S. canneries totaled 124,630 st in the first quarter, 154,219 st in the second, and 128,168 st in the third quarter. Skipjack was the largest component of the first and second quarter raw tuna deliveries, comprising from 43% to 52% of the totals, respectively. Yellowfin tuna was the largest component of the third quarter raw tuna deliveries, comprising 45% of the total.

Tuna delivered to U.S. canneries in the first three quarters of 1989 originated principally in the western Pacific Ocean. Eight nations provided more than 90% of the raw, frozen tuna imported to U.S. canneries in the first quarter of 1989, of which the major suppliers were Taiwan, South Korea and Venezuela. Major suppliers in the second quarter were Taiwan, South Korea and France; in the third quarter the top three were Taiwan, Venezuela and France.

Imports of canned tuna to the U.S. in all three quarters of 1989 exceeded both 1988 and recent (1984-1988) average imports for the same periods.

More details are available in the The Tuna Newsletter, Southwest Fisheries Center, P.O. Box 271, La Jolla, California 92038.

III. INDIAN OCEAN FISHERIES

Review of Indian Ocean Fisheries Completed

Skipjack and yellowfin tuna are becoming increasingly important in catches of Indian Ocean tuna fisheries. The catch of these species in 1986 (262,300 metric tons) was three times the 1981 catch. The major part of this increase is due to catches by the large-scale purse seine fleet, which began to take a significant part of Indian Ocean tuna in 1983. A detailed review of the Indian Ocean fisheries was completed in 1989 by Fishery Biologist Wesley Parks of the La Jolla Laboratory.

Update on the Seychelles Purse Seine Fishery

Data for purse seiners fishing in the area around the Seychelles were received from the Seychelles Fishing Authority and added to Center data bases by Al Coan, mathematical statistician and Diane Pickelsimer, computer assistant. The data bases are available on PC diskettes and are in LOTUS spreadsheets; they cover the period 1983 to the present.

The 1988 fishing season was dominated by vessels from France (20 vessels) and Spain (18 vessels). Also participating in the fishery were vessels from the USSR (4), Mauritius (3), Panama (1), Japan (1) and India (1). Catches of yellowfin and skipjack tunas in 1988 reached a record high of 213,000 t, increasing 32% over catches in 1987. The percentage of skipjack and yellowfin tuna in the catch was 53% and 47%, respectively, and returned to levels recorded in the period 1981-1985. Yellowfin tuna catches showed the highest percent increase, 64%, over 1987 yellowfin catches, whereas skipjack catches only increased 13%.

Catch rates increased from approximately 18 t/day fished in 1987 to 22 t/day fished in 1988. Yellowfin tuna showed the greatest increase in catch rate from 7 t/day fished in 1987 to over 10 t/day fished in 1988.

Catch rates in October of 35 t/day fished were the highest ever recorded in the western Indian Ocean.

In the third quarter of 1989, the number of purse seiners participating in the Seychelles purse seine fishery in the western Indian Ocean reached a record high of 51 (20 French, 22 Spanish, 4 Russian, 2 Japanese, 2 Mauritian and 1 Panamanian). The previous record was 49 vessels in the first quarter of 1985.

Poor fishing experienced during the second quarter of 1989 continued during July and August, with catch rates averaging 11 to 13 t per day's fishing. Catch rates rebounded during September to 26 t per day's fishing, but still remained below the 30 t per day's fishing recorded during September 1988.

Cumulative catches reached 163,200 t through September 1989, an increase of 9% over catches during the same period in 1988. Skipjack tuna dominates the catch, representing approximately 80% of the catch in September and 64% of the cumulative catch for the year.

IV. PACIFIC OCEAN FISHERIES

Pacific Albacore

Summary Completed of 1988 North and South Pacific Albacore Data

Anthony Majors, Christina Perrin (SWFC), and Forrest Miller (IATTC), have completed SWFC Administrative Report LJ-89-19, which summarizes 1988 U.S. Pacific albacore fisheries. Catches of albacore in the northern fishery increased slightly from 2,900 metric tons (t) in 1987 to 4,800 t in 1988, but were still well below the 20-year average of 16,000 t (1968-87). The average size of fish landed in the northern fishery (12.8 lbs), was slightly smaller than that of 1987 (14.9 lbs). Catch rates in fish per standard day's fishing increased from 70 fish per day in 1987 to 117 fish per day in 1988.

Participation in the south Pacific U.S. albacore fishery reached its highest level (43 vessels in 1988) since its start in 1986. Catches for the southern fishery increased substantially from 700 t in 1987 to 3,500 t in 1988. Average size of fish caught was 14.9 lbs.

Long Term Decline Noted in West Coast Albacore Catch Rates

Roy Mendelssohn, with the Pacific Fisheries Environmental Group in Monterey, has been developing predictive models for the West Coast albacore fishery utilizing catch information from the albacore logbook program. As a part of this program, the annual variations in catch rates are being examined. Recent results show that there has been a long-term decline in the number of fish caught per day in the fishery and that the decline has been particularly dramatic in the region which has traditionally provided the bulk of catch from the northern Oregon-Washington portion of the fishery. During the 1960s, median catches averaged nearly 100 fish per day in the northern fishery, and catches exceeding 200 fish per day were quite com-

mon. In the 1970s, median catch per day declined markedly and catches above 200 fish per day became rare. Catch rates continued to decline in the early 1980s; median catch ran around 25 fish per day and catches of 100 fish per day became rare.

North Pacific Albacore Workshop Held

The Southwest Fisheries Center hosted the Eleventh North Pacific Albacore Workshop on May 18 and 19, 1989, at the Center. Twenty-eight participants from Canada, Japan, France, the South Pacific Commission, Taiwan and the United States presented 19 working papers and several information papers relating to the condition of the stock and the associated fisheries. Considerable new data and analyses were made available for scientific review.

Assessment of the condition of North Pacific albacore stock was different and more pessimistic than determined by previous workshops. Several sets of new data pointed to the likelihood that the stock has experienced recruitment failures in at least two recent years. Further, new analyses of catch-per-unit-effort (CPUE) indicators suggest that the adult stock may be at the lowest level seen in recent years. Both major surface fisheries (Japan and U.S.) show long-term declines in CPUE and effort with very low values for recent years. The workshop concluded that the combination of declining CPUE and effort in fisheries which monitor the young stock, and the unknown but possibly high incidental mortalities on small fish from the drift net fisheries for other species, e.g. squid, and the apparently missing or much-reduced abundance of two year-classes, suggest that the stock may be experiencing recruitment problems.

The workshop participants noted that environmental events may have contributed to the problems associated with the stock. A number of recommendations were adopted centering on confirmation of the condition of

the stock and increased monitoring of the much-reduced year-classes as they move through the fisheries.

North Pacific Albacore: Stock Structure and Size Composition

The stock structure of albacore in the North Pacific is presently an unresolved problem. Fishery Biologist Richard Parrish is currently using the extensive length frequency measurements taken in the Japanese baitboat fishery (479,400 fish) and those from the American fishery (318,558 fish) to examine this problem. There is circumstantial evidence which suggests that the traditional U.S. albacore fishery is based on two stocks. A principal piece of evidence is that differences in the growth rates of albacore caught in the northern and southern fishing grounds have been observed (i.e. north and south of 38°N). Growth studies, based on a limited number of fish for which daily otolith counts have been made (98 from the northern area and 127 from the southern area) and from tag and recapture data from 521 fish, indicate faster growth for fish in the southern area than in the northern area. Tag recoveries suggest that there is more interchange of albacore between the Kuroshio Current region and the northern portion of the California Current region than between the Kuroshio and the southern portion of the California Current, and that there may be two stocks.

The North Pacific albacore fisheries are quite seasonal and occur in different seasons in different regions. Also, albacore grow very quickly and the differences in size distributions between regions is heavily influenced by the interaction of these factors. To limit the seasonal bias, the analysis was limited to fish captured in July and August, when the California Current albacore fishery peaks. The data were divided into bands of 5 degrees of latitude for both the Kuroshio and California Current fisheries to show regional patterns in length frequencies. In the July-August period the catch from the Japanese baitboat fishery is dominated by fish taken in the Kuroshio Extension.

The clearest feature of the data is that all of the regions have a mode at 61-62 cm, representing 3-year old fish. This mode dominates the size composition in

each of the regions, with the significant exceptions of the 30 degree bands in the Kuroshio where albacore of this size comprise only a very minor proportion of the size composition and in the most southern 5 degree bands in the California Current where it is the secondary mode. Thus, 3-year old albacore are the same size in July and August in all regions in which they are caught in the North Pacific.

The size of 4-year old albacore is quite a different story. In the California Current region size composition has a mode at 73 cm in the 40, 45, and 50 degree north bands, whereas the mode is at 76 or 77 cm in the 25, 30, and 35 degree north bands. In addition, there is a continuous increase in the proportion of fish larger than 73 cm from the north to the south. In the Japanese baitboat fishery there are modes at either 77 or 78 cm at the 30, 35, and 40 degree north bands; however, the modes of the bulk of the albacore catch in the 30 degree north bands are larger than the mode for 4-year olds.

The evidence from this analysis suggests that the size composition, and presumably the growth rates, of albacore are more similar in the Western Pacific region and the southern portion of the California Current than they are in the northern and southern portions of the California Current or in the northern portion of the California Current and the Western Pacific. Three-year olds appear to be the same size everywhere, and the size of 4-year olds appears to be primarily a function of latitude.

International North Pacific Albacore Conservation (INPAC) Initiative

After the May 1989 North Pacific Albacore Workshop, Southwest Fisheries Center tuna researchers developed a research plan to monitor the albacore population and to collect information to determine factors contributing to the poor recruitment. Called the Internation-

al North Pacific Albacore Conservation (INPAC) Program, the proposed program has three main objectives: 1) determine the condition of the albacore population and causes for poor recruitment using CPUE, LF and other fisheries-based data; 2) evaluate and measure key albacore life history parameters and other influential factors crucial for developing sound management advice (e.g. age/size structure, reproductive potential, stock interactions, habitat requirements); and 3) share the results of these assessments among participating governments and industry representatives. The first such meeting is scheduled for 1991 in Japan, and will be a joint industry/government (U.S. and Japan) conference to review markets, stock trends and industry concerns and trends. The second meeting will be held in 1994. Norm Bartoo, with the La Jolla Laboratory's Pelagic Fisheries Resources Division, has been assigned by the SWFC as the U.S. coordinator for INPAC Program, and recently returned on March 23 from a trip to Japan where he worked with Japanese scientists in Shimizu on albacore statistics, and discussed with officials at the U.S. embassy, Fisheries Agency of Japan and the Japanese tuna industry, the INPAC proposal.

Bartoo Travels to Japan to Discuss Scientific Cooperation on Albacore

At the invitation of The National Research Institute of Far Seas Fisheries (NRIFSF), NMFS scientist Dr. Norm Bartoo spent from February 5 through March 23 at the NRIFSF laboratory organizing a cooperative assessment of the north Pacific albacore stock. It was agreed that Japanese and NMFS scientists would exchange all available albacore data and begin a comprehensive assessment to precisely determine the condition of the stock. Japanese scientists also agreed to review designs of experiments to be conducted by NMFS to estimate unknown albacore mortalities due to driftnet "dropouts". Participating scientists agreed to present the results of the assessment research and conservation recommendations at the 12th North Pacific Albacore Workshop to be held in Shimizu, Japan in mid-1991.

At the Southwest Fisheries Center, actions will be taken to involve scientists and obtain data from Taiwan

and Korea in the cooperative assessment program. SWFC programs will be implemented with other NMFS units to collect driftnet fishery statistics. Analysis of albacore data will be done in cooperation with a Japanese scientist, Hedeki Nakano, who will be staying at the Southwest Fisheries Center in La Jolla for one year starting March 9, 1990. He will be working for the Inter-American Tropical Tuna Commission.

Impacts of North Pacific High-Seas Driftnet Fishing: Recent Scientific Negotiations

High-seas driftnet fisheries in the North Pacific conducted by Japan, Korea, and Taiwan take numerous species of importance to the Southwest Region, including albacore, other tunas, billfishes, and sea turtles. The impacts of driftnet fishing are unknown, but sharp declines in albacore catch rates during the 1980s, when the driftnet fleets expanded, has created deep concern among U.S. albacore fishermen. There is also concern over takes and associated "dropout" mortality of billfishes and other pelagics subject to U.S. jurisdiction under the Magnuson Act. Endangered or threatened sea turtles are also taken incidentally in the driftnets; some of these may originate from nesting colonies in the United States.

During March 2-15, 1990, NMFS scientists from the Southwest Fisheries Center, Alaska Fisheries Science Center and National Marine Mammal Laboratory participated in two meetings in Tokyo, Japan, related to cooperative monitoring of Japan's North Pacific high-seas driftnet fisheries. The meetings were technical and involved scientists from the U.S., Canada and Japan.

U.S. scientists from NMFS reached agreement with Japanese scientists on preparation of a June 1990 report of catch rates in the 1989 Japanese squid driftnet fishery. The report

will cover salmonids, marine mammals, seabirds, sea turtles, albacore, and other species. Data were collected by North American and Japanese observers aboard commercial squid driftnet vessels.

Extensive agreements were established with driftnet nations to monitor driftnet takes, estimate dropout rates, and conduct biological sampling aboard commercial driftnet vessels in 1990.

Summary of the 1989 U.S. Albacore Season

The U.S. west coast albacore fishery in 1989 was very poor, with one of the lowest commercial landing totals ever recorded. The newly developed South Pacific troll fishery for U.S. boats provided very good catches for the 50 boats that participated in 1989. There were approximately 1,900 short tons (st) of albacore landed by commercial vessels fishing off the U.S. west coast in 1989, with a total ex-vessel value of \$2,900,000. There were 4,200 st of albacore landed by U.S. jigboats fishing in the South Pacific, with an approximate ex-vessel value of \$8,400,000. In addition to the commercial catches, sportboats fishing out of southern California landed an additional 75 st of albacore.

There was essentially no U.S. effort during the spring and early summer of 1989 in the "Midway Fishery" for albacore, located in the mid north Pacific between the dateline and about 150°W longitude. Six to eight vessels departed Hawaii in early July and fished eastward towards the mainland, catching albacore of 12-14 pounds as they continued working towards the Oregon coast.

Albacore jigboats fishing off the Pacific Northwest began reporting fair to good catches by mid-July. Boats were fishing 300-400 miles off northern California to northern Oregon and landing albacore of 12-14 pounds, with some fair fishing also reported 100 miles off the Columbia River. By the end of July catches had dropped off and boats were scattered in search of albacore. In early August, albacore of 18-25 pounds were located off the northern tip of Vancouver Island, B.C., and a large portion of the commercial fleet moved northward, fishing in this area until early Sep-

tember when decreasing catches and inclement weather forced most of the vessels to move southward. Vessels continued to report good but spotty fishing 400 miles off the Oregon coast on albacore of 12-14 pounds during August. In mid-September the average fish weight in this area dropped to 8-9 pounds and weather conditions became poor, convincing most vessels to terminate their season. Coastal waters 50-200 miles off Oregon and Washington failed to produce any substantial catches of albacore. Vessels reported scattered fish over all areas, but found none of the temperature frontal boundaries with which concentrations of albacore are usually associated.

In early August, commercial catches of albacore were reported from 100-150 miles off northern California, from Ft. Bragg northward to Cape Mendocino. Although there were concentrations of fish in this area through early September, very frequent periods of high winds and heavy seas prevented vessels from fishing for more than 2-3 days at a time and limited catches from this region. Some albacore were reported 130 miles off central California during the season but there was very little fishing effort in this area.

Sportboats fishing out of southern California began catching albacore of 6-8 pounds 200 miles south of San Diego the first week of July. The albacore remained in this area until mid-August, when they moved to within 90 miles of San Diego. Sportboats reported that the albacore were being caught along with bluefin tuna, skipjack tuna, yellowfin tuna and bigeye tuna, as well as mahimahi and large numbers of yellowtail. Sportboat catches continued from 50 to 130 miles south of San Diego through early October. Due to the small size of the albacore off southern California there was no commercial fishing effort.

There were 50 U.S. trolling vessels which fished in the South Pacific albacore fishery. Vessels reported good catches by mid-December 1988, with most of the fleet on the

grounds by early January. Albacore from the south Pacific fishery were 8-40 pounds, with most of the fish weighing 16-25 pounds. The best catches were along 38°S from 145°-165°W, with daily averages of about 300 albacore per day and high catches of 1,600 fish. Most of the vessels were able to complete two full trips before the onset of the typhoon season in mid-March terminated the southern season.

SPAR Workshop Held in Fiji in June

The Southwest Fisheries Center was represented at the second meeting of the South Pacific Albacore Research (SPAR) group, held on June 12-21 in Suva, Fiji. At the meeting, South Pacific governments expressed alarm over the exceptionally fast development of the albacore surface fishery and of high-seas gill netting. The participants reviewed what is known about the stock, and outlined the requirements to enable accurate assessments and protect the productivity of the population. The group was particularly concerned about incomplete or inadequate data received from the various fisheries. They warned that if inadequate data continue to be supplied from the fishery, accurate assessments and precise management advice should not be expected.

SPAR was organized in 1986 to facilitate data exchange and research among those studying the population biology and resource potential of south Pacific albacore. The group consists of researchers from the U.S., New Zealand, France and the South Pacific Commission

Gary Sakagawa, chief of the Pelagic Fisheries Resource Division, La Jolla, and Jerry Wetherall, head of the Pelagic Resources Program in Honolulu, attended the meetings. SWFC documents on the following topics were submitted to the workshop: observations on drift gillnet selectivity for albacore inferred from various surveys (Norm Bartoo and Dave Holts); current status of South Pacific albacore data on SWFC data bases (Al Coan and Doug Prescott); current outlook of stock condition and fisheries for north Pacific albacore (Gary Sakagawa); South Pacific albacore age and growth (Jerry Wetherall); and abundance indexing using historical longline data (Wetherall).

Hawaii's Fisheries

Hawaii Midyear Fishery Reports

The source of greatest controversy in Hawaii's commercial fisheries in 1989 is the emerging conflict between a group of recently arrived longline fishing boats from the Gulf of Mexico and small-scale recreational, commercial, and charter boats off Oahu's Waianae coast and on Haleiwa's fishing grounds. The topic dominated discussions at the July 24-26, 1989 meeting of the Western Pacific Regional Fishery Management Council in Kahuku, Oahu. By mid-August, the two sides involved in the conflict had attended several meetings held by Council Chairperson William Paty, and informal "rules of the road" had been proposed. Neither Federal nor State of Hawaii regulations on the pelagic fisheries have been applicable to this situation.

The potential for conflicts over markets, resources, and gear has increased over the past couple of years as the longline tuna fleet expanded--from as few as 16 vessels in 1980 to 37 vessels in 1987 to at least 65 vessels in 1989. At the same time, the commercial, charter boat, and recreational trollers have expanded in number and are fishing farther from shore. Some of the newer longline vessels fish their gear in shallower depths (some immediately subsurface) and closer to shore, catching a higher percentage of striped marlin, *Tetrapturus audax*, and yellowfin tuna, *Thunnus albacares*, than most of Hawaii's longline fleet. This summer, a few of the new longline boats began fishing near fish aggregating devices (FAD's) located 3.5 to 5 miles off the coasts of Oahu and Kauai. This led to a period of intense gear competition, because over the past few years, the FAD's have been used almost exclusively by trollers. Although a number of Honolulu Laboratory scientists have been asked for technical assistance during the controversy, information on the biological and economic interactions in these nearshore pelagic fisheries is, at best, weak.

Meanwhile, the longline fishery for pelagic fishes and tunas remained strong through the first half of 1989. Landings by the longline fishery in the first quarter of 1989 were similar to the last quarter of 1988, which itself was a record. Tunas comprised 65% of the landings, most of which were bigeye tuna, *Thunnus obesus*. The largest component in the non-tuna landings was striped marlin. Substantial landings of broadbill swordfish, *Xiphias gladius*, also were reported this year, the first time that swordfish has been a primary target for Hawaii's boats. Most of the swordfish were exported to the east coast of the U.S.

Detailed estimates of troll and handline landings in 1989 are not available, but 1989 did not appear to be a particularly good year, intensifying the interaction problems with the longline fleet.

Hawaii Longline, Handline and Troll Tuna and Pelagic Landings

Hawaii's longline fishery has expanded dramatically over the past 3 years, a trend that is continuing according to the 1989 midyear data. During January-June 1989, an estimated 529 longlining trips were taken by 66 vessels. Landings of the pelagic management unit species by longline vessels were 3.5 times higher than during the same period in 1987 (2.2 times higher than in 1988). Tuna landings were up 45% from midyear 1987 (15% from 1988). Bigeye tuna, comprised the largest individual component of the longline catches (29%), whereas striped marlin, was second (19%), similar to catches during the same period in 1988 and 1987.

During January-June 1989, the landings of pelagic fishes by the handline and troll fishery were down 30% from midyear 1988, and down 42% from 1987. The greatest declines occurred in landings of mahimahi, *Coryphaena hippurus*; ono (wahoo), *Acanthocybium solandri*; and yellowfin tuna. Conversely, bigeye tuna landings increased substantially. The largest individual component of the catch was yellowfin tuna (28% of the total), whereas mahimahi and ono (combined) constituted 30% of the total, and Pacific blue marlin, *Makaira mazara*, 16% of the total. Species composition fluctuated significantly between years.

Hawaii Samples Collected for Northeast Fisheries Science Center

Kurt E. Kawamoto, fishery biologist, acquired and shipped samples of yellowfin tuna, albacore, spiny and slipper lobsters, and macrobrachium prawns for a Northeast Fisheries Science Center (NEFSC) project on the identification of processed seafood products through monoclonal antibodies (MCA's). According to Stephen Mayfield, a NEFSC researcher, mice are "immunized" with water soluble protein extracts from the seafood. Over a period of months, a mouse's immune system builds up antibodies which concentrate in the spleen. The mouse is then sacrificed and its spleen removed. The spleen cells are fused with cancer cells from the mouse to create "immortal" hybridomas which secrete the antigens used in species identification. The NEFSC plans to develop a series of MCA's to differentiate a number of important seafood species, which include the western Pacific samples.

South Pacific Tuna Fisheries

NMFS Participates in Planning Meeting of Forum Fisheries Agency

The National Marine Fisheries Service (NMFS) was represented at the Third Technical Subcommittee Meeting of the Forum Fisheries Committee in Honiara, Solomon Islands, in September 1989, by Honolulu Laboratory Director George W. Boehlert. This meeting, entitled "A Conference on the Management and Development Strategies in South Pacific Fisheries," was called in honor of the 10th anniversary of the Forum Fisheries Agency (FFA). The goals of the meeting were to review the first 10 years of progress by the FFA and to develop a work plan for the coming decade. The meeting was attended by fisheries officers or ministers of all member

countries; observers came from a variety of regional and international research organizations, donor agencies, and universities.

A variety of papers was presented at the week-long meeting: a review of FFA activities for the last decade, an overview of financial aid patterns, policy and activity reports from agencies within and outside the region, and different interpretations of trends in fisheries research, economics, management, and law of the 1990's as they relate to the South Pacific. Boehlert presented two NMFS working papers, one on US fisheries research activities within the Pacific and another on fisheries research in the 1990's.

The papers served as background for subgroup meetings on management, development, legal, research, and economic aspects of South Pacific fisheries. Each group was charged with making recommendations on the objectives and work of FFA in the coming decade and prioritizing the recommendations. Final reports by the chairs of the subgroups to the plenary session were discussed and used to draft a "Corporate Plan," which would serve as a guidepost for FFA activities over the next decade. The final plan was to be reviewed and approved by the meeting of ministers the following week.

The FFA has been successful in assisting Pacific island nations in developing fisheries and in group negotiations with larger, deepwater fishing nations. Their corporate plan presents an ambitious effort to continue and expand their activities over the next decade.

User Manuals and Documentation Completed for Annual Report Preparation

At the Honolulu Laboratory, user manuals and computer program documentation for preparing annual report modules on the status of the pelagic fisheries in American Samoa, Guam, Hawaii, and the Commonwealth of the Northern Mariana Islands (CNMI), were completed in June by Robert A. Skillman and Computer Programmer Reese Tokunaga contracted by the Western Pacific Regional Fishery Management Council. The report modules are to be submitted by each island fisheries office and then used by the Council's

Pelagic Plan Monitoring Team to prepare its annual report on the status of the managed pelagic fisheries.

The procedures consist of computer programs to process data on commercial landings and to produce tabular and graphics summaries to meet requirements listed in the Pelagic Fishery Management Plan (at least as interpreted by the Team). For American Samoa, Guam, and the CNMI, the computer programs are written in dBASE III Plus, whereas the programs for Hawaii are written in SAS. The procedures for graphics were developed with the software package CHART-MASTER to produce publishable-quality charts.

With the completion of these computer programs and graphing procedures, the fisheries offices in American Samoa, Guam, Hawaii, and the CNMI will be able to complete their own annual report modules with little or no support from the Southwest Fisheries Center and the Council.

Logbook Data Base Archiving

The United States entered into a South Pacific Regional Tuna Treaty with 16 South Pacific island states 2 years ago on June 15, 1988. The Treaty allows U.S. tuna seiners to apply for licenses, and fish for yellowfin and skipjack tuna within the Treaty area. As part of the Treaty, the vessels must submit logbook reports and unloading reports to the Southwest Region and the Foreign Fisheries Agency (FFA). The Southwest Region also samples landings from licensed vessels for sizes of tuna caught and composition of fish species in the catch. The data are then transferred to and archived on computers by the Southwest Fisheries Center. Al Coan, mathematical statistician, and Doug Prescott, computer programmer, maintain the data base, providing the computerized files to the FFA on a bi-monthly basis, and working up data summaries for the FFA on request. An annual report on the 1989 logbook data was com-

pleted in February 1990 and submitted to the FFA.

Data collected from US purse seiners fishing in the Treaty area during August 1, 1989 to October 1, 1989, were submitted to the FFA. The submission consisted of 16 catch report forms, 209 length-frequency samples (93 yellowfin, 64 skipjack and 52 bigeye), and 111 unloading forms.

Data collected for the first year of the Treaty, June 1988 to June 1989, are being summarized. Preliminary results show approximately 130,200 st of tuna (109,700 st skipjack and 20,500 st of mixed yellowfin and bigeye) were landed by 32 US purse seiners in approximately 138 separate landings. The majority of the landings was made in American Samoa; some direct landings or transshipments were made in Puerto Rico (1,853 st), Japan (824 st), Indonesia (719 st), Thailand (311 st), Philippines (183 st) and Australia (107 st). High catches of over 10,000 st per month were made in July 1988 and January, March and June 1989. Most of the skipjack caught were between 50 and 60 cm long; the yellowfin and bigeye tunas were between 45 and 75 cm long. Species composition samples indicate that approximately 5,500 st of bigeye tuna (27%) are included in the 20,500 st of mixed landings of yellowfin-bigeye.

Tuna Behavior and Physiology Studies

Research on "Burnt Tuna" Progressing

Research on "burnt tuna" is being conducted by Cheryl Watson, a graduate student in the Department of Physiology, John A. Burns School of Medicine, University of Hawaii, utilizing the Honolulu Laboratory's Kewalo Research Facility. "Burnt tuna" is a product quality problem affecting large yellowfin tuna and bigeye tuna intended to be sold for "sashimi" (i.e., for raw consumption). Although perfectly edible when cooked, burnt tuna is considered unsuitable for the sashimi market and therefore commands only a small fraction of the price of top quality fish.

An exact measure of the cost of burnt tuna to the Hawaiian tuna fishing industry is not available, but the

total, annual, direct ex-vessel losses are estimated at \$3.0 million. (This figure does not take into account retail losses or potential export markets that remain undeveloped.) The ex-vessel value of yellowfin and bigeye tuna landings in Hawaii was \$12 to \$20 million in 1987, so the importance of the burnt tuna problem can be easily appreciated. Reliable, cost-effective techniques to prevent or minimize this problem are clearly needed.

Watson's research is centered on the new hypothesis that burnt tuna is not directly caused by acidity and high muscle temperature that occur during capture, but rather is a result of digestion of specific muscle proteins by calcium-activated proteases (i.e., enzymes that cause protein destruction), which become activated post-mortem. This theory was originally delineated by Peter W. Hochachka and Richard W. Brill ("Autocatalytic pathways to cell death: a new analysis of the tuna burn problem," *Fish. Physiol. Biochem.* 4:81-87, 1987).

Watson has expanded this basic hypothesis to include the theory that adrenalin and noradrenalin, which are hormones that fish produce in response to stress, accelerate the activity of calcium-activated proteases ("A comprehensive theory on the etiology of burnt tuna," *Fish. Bull.* 86:367-372, 1988). The expanded theory explains why the "burnt tuna syndrome" occurs more often in fish caught by handline and rod and reel, and in female fish caught during the summer. It also explains why other measures to reduce the incidence of burnt tuna, such as chilling and brain destruction are relatively ineffective.

Using an electron microscope, Watson has found that samples taken from burnt tuna showed characteristic deterioration in muscle structures known to be specifically attacked by calcium-activated proteases (the Z-disk was selectively removed from the sarcomeres of burnt tuna), confirming the original hypothesis. More recently, biochemical analysis of burnt tuna, conducted by using SDS-PAGE electrophoresis, indicates that a

specific protein appears to be attacked by the calcium-activated proteases. The specific identity of this "marker protein" is yet unknown, but immunological testing (Western blot technique) is being used to determine its identity. More important, since this protein is a reliable indicator of burnt tuna, it may eventually be possible to develop a test that obviates the current practice of quartering tuna suspected of being burnt. This need to cut open the fish to check for burnt tuna devalues the fish even if it is not burnt.

Heretofore the burnt tuna syndrome has been recognizable only in wholesale fish markets. Work is now under way to reproduce the syndromes in the laboratory, by using small, isolated muscle samples. Work done in this manner to date indicates the proposed theory is correct and that the muscle deterioration in burnt tuna is due to a calcium-based proteolysis. Surprisingly, the biochemical causes of burnt tuna also appear to be the same as those causing damage to the human heart muscle during heart attack and those causing some forms of muscular dystrophy. Work on burnt tuna may therefore have implications to medical science as well as to fishery science.

Manuscript on Swimming Physiology of Tunas Completed

The manuscript "Cardiorespiratory responses of swimming yellowfin tuna and skipjack tuna, *Katsuwonus pelamis*, exposed to acute hypoxia" by Peter G. Bushnell (University of British Columbia) and Richard W. Brill (NMFS Honolulu Laboratory), has been completed and submitted for publication in *Physiological Zoology*. This manuscript describes experiments on swimming fishes, and is part of a series of three papers describing the reactions and physiological tolerances of tunas to reduced levels of ambient oxygen (hypoxia). The first manuscript of the series ("Cardiorespiratory responses of skipjack tuna, yellowfin tuna, and bigeye tuna to acute reductions in ambient oxygen" by Bushnell, Brill, and Robert E. Bourke (Hawaii Institute of Marine Biology, University Of Hawaii)) describes experiments on multi-instrumented, restrained animals, and has been accepted for publication in the *Canadian Journal of Zoology*. The recently submitted manuscript examines the heart rate responses to acute hypoxia in swimming skipjack and yellowfin tunas. Reductions in heart rate, a common response of fishes to this

situation, became significant when oxygen tension (PO_2) reached 149-130 mmHg in skipjack tuna and 129-110 mmHg in yellowfin tuna. Heart rate decreased in both species despite concomitant increases in swimming speed. Heart rate continued to decrease along with PO_2 in yellowfin tuna, but in skipjack tuna, it increased at the lowest oxygen levels reached (89-70 mmHg).

Also examined were changes in ventilation volume during hypoxia in yellowfin tuna; these changes were monitored by a continuous infusion dye dilution system. As oxygen levels fell, ventilation volume increased. At the lowest oxygen levels (109-90 mmHg) reached, ventilation volume was 45% higher than normal.

Data from these experiments were used to develop models capable of predicting oxygen demand and delivery, maximum sustainable (i.e., aerobic) swimming speeds, and minimum survivable oxygen levels for yellowfin and skipjack tunas. The results from these models indicate that, contrary to commonly held opinions, the cardiorespiratory system of tunas has not evolved to permit very high, sustained swimming speeds, but rather, to permit high rates of oxygen delivery at low swimming speeds for the rapid repayment of oxygen debts.

Pacific Billfish Programs

Pacific Blue Marlin Tracked Successfully

Two Pacific blue marlin carrying depth-sensitive, ultrasonic transmitters were tracked successfully by Fishery Biologist Richard W. Brill of the Honolulu Laboratory, Kim Holland of the University of Hawaii's Institute of Marine Biology, and NOAA Corps Officer LTJG Scott Sullivan off the Kona Coast, island of Hawaii, July 28 to August 6, 1989. The fish were caught and released by anglers par-

ticipating in the 31st Annual Hawaiian International Billfish Tournament in Kailua-Kona.

Both fish behaved remarkably similar to three marlin tracked in the summer of 1988, although they were captured and released about 10 nmi south of last year's capture site. After release, the two fish moved directly offshore and along parallel courses for approximately 10 nmi. This offshore movement appears to be a stereotypical response of marlin to the stress of capture. Both fish eventually turned north and proceeded in that direction for the duration of the tracking. With respect to swimming depth, both fish moved up and down only within the mixed layer (i.e., the 50-100 m layer of uniform water temperature). Further analysis of the data is proceeding.

Pacific Cooperative Marine Game Fish Tagging

In 1988, the Service's (NOAA/NMFS) journal, "Marine Fisheries Review", published a detailed review covering the results of striped marlin tagging about the southern tip of Baja California, Mexico. The title of the article is "Striped marlin (*Tetrapturus audax*) migration patterns and rates in the northeast Pacific Ocean as determined by a cooperative tagging program and their relation to resource management," by J. L. Squire, Jr. (47(2):26-43). This article discusses results from 12,000 striped marlin tagged and released in that area.

In 1988, billfish anglers tagged and released 1,106 billfish, a decrease of 464 billfish tagged over the number tagged in 1987. In addition, anglers used billfish tags to tag 49 other fish species, including sharks for a total 1,155 fish tagged. A total of 732 striped marlin, 157 blue marlin, 7 black marlin, 150 sailfish and 13 short-billed spearfish, plus 96 billfish, unidentified as to species, was tagged and released in 1988. Some of these fish were reported tagged in the Gulf of Mexico, Caribbean Sea, and Atlantic Ocean.

Key individuals participating in the billfish tagging process are the charter boat and private boat captains. It is these individuals who have frequently taken the time to obtain the tags and encourage their use by the anglers. In Hawaii, the tagging of billfish increased during the past 3 years, thanks to the support given by

the Pacific Game Fish Research Foundation, Kona, HI, and the Hawaiian boat captains.

In 1988, tagged fish recaptured were 16 striped marlin, 1 blue marlin, 1 sailfish and 1 black seabass.

Eastern Pacific Striped Marlin Fishery Reviewed

The striped marlin resource supports very important commercial and recreational fisheries in both the Pacific and Indian Oceans. World-wide commercial landings have averaged 16,600 t in recent years; 20% of which is taken in the northeast Pacific. The greatest portion of this is delivered to the Japanese "sashimi" market in Tokyo where it currently sells for about \$8,500/t. Catch rates indicate the greatest abundance is in the eastern tropical Pacific Ocean within an area south from Magdalena Bay, Baja California, to the Revillagigedo Islands, and northeast toward Mazatlan, Mexico.

Although generally considered highly migratory, striped marlin do not appear to make long, annual journeys as do albacore and bigeye tuna. Their movements may better be described as opportunistically diffusive and are dependent on the age and condition of the fish. The major spawning area is in the central-north Pacific. Young fish concentrate in the food-rich waters of the north- and southeast Pacific where they grow and mature. As they attain lengths greater than 200 cm they tend to move back to the spawning areas of the central-north Pacific.

The commercial longline fishery for striped marlin in the northeast Pacific is primarily Japanese, but also includes vessels from Taiwan and South Korea. Within Mexico's 200-mile exclusive economic zone (EEZ), longline vessels are entirely Mexican or Mexican-Asian joint ventures. There is currently no commercial fishery for striped marlin off the west coast of the United States although a harpoon fishery existed during the 1930's. In 1937, striped marlin were desig-

nated as a sport-only gamefish and subsequently prohibited from commercial sale in or for export from California.

Japanese longline vessels began fishing for tuna and billfish in the central Pacific in the mid 1950's. By 1963 they were focusing considerable effort off Mexico's coast. Between 1963 and 1971 they landed an average of 220,000 striped marlin (13,600 t) per year. This catch peaked in 1968 at 338,000 fish (21,000 t). Total effort (east of 130°W) increased to over 95 million hooks per year by 1977. Catch decreased during this period from 230,000 fish in 1971 to about 65,000 in 1977. Mexico extended its territorial jurisdiction in 1976 which virtually halted foreign fishing effort between 1977 and 1980. Longline fishing resumed in 1980 and by 1983 pressure from the Mexican tourism industry resulted in fewer joint-venture permits and a commercial fishing limit within 30 nm of shore. By 1987 there were at least 14 commercial longline vessels fishing striped marlin within Mexico's EEZ. Also during this time Mexico's own longline and drift gillnet fisheries for billfish were expanding.

The recreational fishery along the west coast of North America represents about 14% of the total eastern Pacific catch. Although comparatively small, this fishery draws major economic and political attention in both Mexico and the United States. Recreational catch rates for striped marlin off the tip of Baja, California, Sur averaged 0.6 to 0.9 fish per angler day in the 1960's. This declined to 0.29 by 1977 but enforcement of Mexico's EEZ regulations had a positive effect on angler catch rates which increased through 1980 to 0.61 fish per day. During the period 1981 to 1987 CPUE fluctuated between 0.32 (1984) and 0.61 (1982). Catch rates off southern California have been fairly constant at 0.10 fish per day. Although 1989 was a near record year with over 2,000 fish landed, the average annual catch in southern California is about 800 fish.

The status of the northeast stock was re-examined using effort data standardized to account for the change in effort directed to deep longlining for bigeye tuna in the 1970's. Total longline catch for the Japanese fleet showed a decreasing trend through 1985 after peaking in 1968. Total effort in the North Pacific peaked in the mid-1960's and remained heavy through 1985. Al-

though catches were sustained over a wide range of fishing effort, CPUE has remained relatively steady throughout the period with no indication of a clear trend. Although appearing healthy at this time, there is reasonable evidence that intense, directed effort close to centers of high abundance, such as around the tip of Baja California, reduces abundance in those areas. Commercial fisheries in other parts of the North Pacific can influence catch rates in the northeast Pacific as well. High seas drift net fisheries which target squid and albacore, have developed rapidly in the last few years. The catch of striped marlin by these fisheries is not known, however the tremendous amount of effort employed by these fisheries might indicate large catches of striped marlin, which could be potentially harmful to the population.

Interaction between the commercial longline fisheries and the sport fishing and tourist industries in both California and Mexico is also significant. Although the sport fishing industry catches only about 14% of the total eastern Pacific take of striped marlin, it has tremendous financial and political clout. The sportfishing industry has been effective in Mexico in reducing the number of longline permits issued and in closing specific fishing grounds to all commercial fishing.

The striped marlin stock in the North Pacific appears healthy at this time. Current information indicates a healthy fishery will continue if fishing effort, both within and beyond Mexico's EEZ, does not greatly increase. If management of striped marlin becomes necessary, managing the fishery in local areas rather than Pacific-wide might be an effective strategy for consideration.

1988 Pacific International Billfish Angler Survey Results

Results of the 1988 Pacific International Angler Survey have been tabulated. The Survey, which was started in 1969, is tabulated from responses to postcard inquiries. Information is gathered from participating billfish

anglers on the number of days during the year they fished for billfish, and the number of billfish caught by species (striped marlin, blue marlin, black marlin, sailfish, short-billed spearfish, and swordfish).

Information for 1988 was collected in the Pacific, Indo-Pacific and Indian Ocean area for 11,304 angler days and a total reported catch of 6,589 billfish, or 0.58 billfish per angler day. In 1987, 14,847 billfish anglers reported catching 6,625 billfish for a catch rate of 0.44 billfish per angler day. The angler catch rate for 1988 (0.58 billfish per day) is near the value obtained during the first years of the survey (1969-1972, 0.55 billfish per day); however, the 1988 totals include considerably more catches of sailfish, a species that normally has a higher catch rate than the marlins.

For southern California, 2,993 angler days resulted in a catch of 322 striped marlin, equaling a catch rate of 0.11 billfish per day. A striped marlin catch rate of about 0.10 billfish per day is a normal rate for this area. Other areas having substantial catches of striped marlin are found about the southern tip of Baja California Mexico, and off Ecuador. Two thousand forty-four billfish angler days about the tip of Baja California yielded 1,218 striped marlin, for a catch rate of 0.48 billfish per day. This catch rate is down from the 1987 survey result of 0.60 billfish per day. Ecuador normally has the highest striped marlin catch rate of any area sampled. In 1988, 320 billfish angler days were reported in Ecuador with catches of 168 striped marlin for a catch rate of 0.52 billfish per day, down considerably from the 1987 record of 0.70 billfish per day.

A location consistently having high catch rates for blue marlin is the Hawaiian Islands. Mauritius in the Indian Ocean, and Guam, though not reporting many angler days (compared to Hawaii), also appear to have good catch rates for blue marlin. In Hawaii, 1,479 billfish angler days were reported, with anglers catching 320 blue marlin for a catch rate of 0.22 fish per day. The catch rate in 1988 was up slightly from that observed in 1987 (0.20 fish per day).

The center of black marlin fishing in the Pacific is off the Queensland area of Australia. This species is also taken by anglers in the Indo-Pacific area (Malaysia, Thailand). For 1988, Australian anglers (614) reported catching 115 black marlin for a catch

rate of 0.19 fish per day. In 1987, and for several years previously (from 1978-1987), the catch rate has remained between 0.47 and 0.58 fish per day. The 1988 survey results indicate a substantial drop in catch rate for black marlin.

Highly productive areas for sailfish are to be found off southwestern Mexico, Central America, eastern Africa and the mouth of the Persian Gulf. In 1988, a record billfish angler catch rate was observed for sailfish off Costa Rica with 334 angler days with anglers catching 886 sailfish. The record average catch rate was 2.65 sailfish per day. Catch rates for sailfish were: 1.05 fish per day off Acapulco, Mexico; 1.21 fish per day off Panama; 1.24 fish per day off Kenya; and 2.00 fish per day off Dubai, United Arab Emirates.

The 1989 Billfish Angler Survey is now in progress in cooperation with the International Game Fish Association.

Squire Receives Award

The Billfish Foundation headquartered in Miami, Florida, awarded Fishery Biologist James L. Squire, Jr., Southwest Fisheries Center, La Jolla, the Foundation's 1989 Conservation Award for Individual Scientific Achievement. The Billfish Foundation is a non-profit organization whose purpose is to promote and encourage research and conservation of billfish worldwide, with the goal of ensuring the future of all billfish species.

Squire was presented an engraved plaque by Chairman of the Board Winthrop P. Rockefeller, at the Foundation's Annual Conservation Awards Meeting held in Ft. Lauderdale, Florida, October 25, 1989.

Squire's research on tunas and billfishes started in the northwest Atlantic in the 1950s. Upon moving to the west coast in 1962, he established the cooperative marlin gamefish tagging program and since then, has worked

closely with sport fishermen, angler clubs, and conservationists to make the program a success. The cooperative program has provided information leading to a better understanding of the migratory patterns of billfish in the Pacific. His research also involved determining the effect of environmental changes on the distribution of billfish and other coastal gamefish species, and trends in catch rates of billfish anglers. The annual survey, the International Pacific Billfish Angler Survey, was established in 1969 to obtain data on anglers for his research.

V. RESEARCH IN SUPPORT OF THE 1972 MARINE MAMMAL PROTECTION ACT

Introduction

In implementation of the Marine Mammal Protection Act (MMPA) of 1972, the Southwest Fisheries Center conducts a program of research directed toward understanding the abundance and biology of dolphins associated with the purse-seine fishery for tunas in the eastern tropical Pacific Ocean (ETP). The objective of this research is to provide estimates of the status of stocks of these dolphins for use in preparing an environmental impact statement governing the taking of marine mammals associated with the fishery.

Voluntary 'Dolphin-Safe' Tuna Policy Announced

On April 12, 1990, H. J. Heinz Co. (StarKist Foods) announced it would only sell tuna which was not caught in association with dolphin. The new policy reportedly was made to save dolphin lives and protect them from harassment and serious injury which occurs in tuna fishing. Bumble Bee Seafoods and Van Camp's Chicken of the Sea immediately announced similar pledges. These three companies control about 70 percent of the U.S. retail market for canned tuna.

NMFS and several environmental groups endorsed this voluntary action as a means of reducing dolphin mortality. The environmental groups continued to support federal legislation currently before the House and Senate, calling for mandatory 'dolphin-safe' labeling backed by trade sanctions for non-compliance.

The new tuna purchasing policy will have a direct effect on fishing strategy of the U.S. and foreign fleets supplying light meat tuna. Currently, about 75 percent of purse seine sets made on yellowfin tuna in the eastern tropical Pacific are in association with dolphin. Tuna caught with dolphin are older and larger fish which are caught further offshore. They command a higher price as their yield for canning is greater than from smaller fish. Under the new policy, fishermen will be forced to fish for smaller tuna at a lower price.

The American Tunaboat Association (ATA) representing 29 U.S. vessels fishing in the eastern Pacific called the new policy discriminatory as it would drive the U.S. vessels out of the fishery and allow foreign vessels to continue killing dolphin. The ATA said they are being wrongfully penalized after making significant efforts in reducing dolphin mortality from nearly 400,000 in 1972 to 12,643 in 1989. Vessel owners are predicting that some 15-17 larger seiners will try to move to the western Pacific tuna fishery, the remaining smaller ones will be sold off or be tied up, as catching smaller tuna not associated with dolphin is not economically viable. There are currently 35 seiners licensed to fish under the South Pacific Tuna Treaty which allows up to 50 licenses a year.

The impact of the new tuna policy on foreign nations catching and exporting light meat tuna from the eastern tropical Pacific (ETP) to U.S. markets is not yet known. Currently five nations (Ecuador, Mexico, Panama, Vanuatu, Venezuela) are fishing ETP tuna associated with dolphin and meet the requirements of the MMPA which allows U.S. importers to purchase their tuna. These nations, fishing in the ETP, caught nearly 300,000 tons of light meat tuna in 1989 and according to preliminary information, will have killed between 60,000 and 80,000 dolphin. About 30 percent of this foreign-caught tuna was purchased by U.S. firms. The importance of the U.S. market, however, varies by nation. In 1989, the percent of ETP catch exported by nation was: Ecuador 31%,

Mexico 11%, Panama 31%, Vanuatu 72%, and Venezuela 48%. These nations are already laboring under the MMPA requirements to have regularity programs and dolphin mortality rates comparable to those of the U.S. or be embargoed. There are indications that Mexico and Panama believe they will be embargoed late this summer. Other nations are reportedly reviewing alternative market strategies should they be embargoed. A major concern appears to be whether the European market will continue buying dolphin-caught fish over the next few years.

Details on the implementation of the voluntary tuna purchasing policy are not fully known at this time. Public statements by company officials imply that NMFS and Inter-American Tropical Tuna Commission (IATTC) observers will confirm whether the tuna vessel chased, encircled or caught any dolphin on a trip. Confirmation would pose no problem on U.S. tuna vessels fishing in the ETP where currently there is 100 percent observer coverage. The IATTC administers the international observer program to meet the MMPA requirements under which foreign nations having fleets of 10 vessels or more must have 33 percent observer coverage and fleets having five to nine vessels must have 50 percent observer coverage. The procedure for U.S. companies receiving confirmation that foreign catches were not taken with dolphin has not been announced.

It is still too early to assess the full impact of these developments on Southwest Fisheries Center research activities; however, the Center Management Team was able to discuss the issues at recent SWFC/SWR Strategic Planning meetings in April 16-18, 1990.

SWFC Participates in NAS Committee on Dolphin-Safe Alternative Fishing Methods to Purse Seining

Currently the National Academy of Sciences (NAS) committee on ways to reduce porpoise mortality associated with tuna fishing in the eastern tropical Pacific is reviewing scientific and technical information relevant to promising new techniques for finding and catching yellowfin tuna that do not involve taking porpoises. These techniques include locating and

catching tuna that are not associated with porpoise, breaking the tuna-porpoise bond prior to encirclement, and modifying existing purse-seining techniques. This study was mandated by the Marine Mammal Protection Act, as amended in 1988. To date, the NAS committee has met twice (December 4-5, 1989 in Washington, DC and January 31-February 3, 1990 in Irvine, CA). Also, one of two scheduled progress reports has been received. The committee plans to have a draft report completed by the end of June 1990 and a final report by September 1990. A third committee meeting was held April 21-22, 1990. As of February 1990, Dr. Douglas P. DeMaster, SWFC, has been assigned the duty of Contract Office's Technical Representative (COTR).

Effects of Dolphin Group, Percent Coverage, and Fleet Size on Estimates of Dolphin Mortality Derived From Tuna Vessel Observer Data

Records of dolphins killed incidental to purse-seining for tuna by U.S. registered vessels fishing in the eastern tropical Pacific Ocean during 1987 were analyzed by Liz Edwards to assess the effects of three factors on estimates of dolphin mortality incurred by an entire fleet, when only a portion of the fleet is actually observed. Data from 1987 were used because this is the first year that nearly 100% of trips carried observers. The three factors were 1) dolphin group, 2) percent coverage (percent of fishing trips observed by scientific technicians), and 3) fleet size. Estimates were derived using the ratio estimator (kill/day) for eight dolphin groups (total dolphins, northern offshore spotted dolphins (*Stenella attenuata*, eastern spinner dolphins (*Stenella longirostris*), whitebelly spinner dolphins, unidentified spinner dolphins, common dolphins (*Delphinus delphis*), striped dolphins (*Stenella coeruleoalba*), and other dolphins),

for simulated fleet sizes of 33, 20, 10 and 5 boats, and simulated sampling levels of 25%, 33%, 50%, 75%, and 96% observer coverage.

Four statistical aspects of these mortality estimates were investigated to assess the effects of the three factors named above, on the estimates: 1) relative bias of the estimate, 2) coefficient of variation of the estimate, 3) frequency distributions of replicate estimates, and 4) 95% confidence intervals of replicate estimates.

Mortality estimates and their statistical (sampling) characteristics were affected in decreasing order of influence by dolphin group type, percent coverage, and fleet size. The strongest control on estimates was the characteristics of the data contributing to the estimates; for groups with relatively frequent and relatively similar kill/trip (e.g., total dolphins), a given level of accuracy and precision could be achieved with relatively low percent coverage even with relatively small fleets. Intermediate levels were adequate for groups with intermediate data characteristics (e.g., whitebelly spinner dolphins, with relatively infrequent but relatively homogeneous kills), however, for dolphin groups with relatively rare and heterogeneous kill/trip (e.g., common dolphins), much higher levels of coverage are required to achieve the same level of accuracy and the level increases with smaller fleets.

As specific examples, coefficient of variations (CVs) 20% or less could be achieved for estimates of total annual mortality given 25% coverage of a fleet of 20 boats, or 50% coverage of a fleet as small as 5 boats. CVs of 20% or less for whitebelly spinner dolphins required coverages of at least 75% for a fleet of 5 boats, and at least 50% for fleets of 20 boats. CVs of 20% or less could not be achieved for estimates of common dolphin annual mortality with coverages less than 100%, at any fleet size.

Because neither fleet size nor dolphin group type can be controlled by a sampling program, the only alternative available to achieve given levels of accuracy and precision in estimates of dolphin mortality is to manipulate the level of observer coverage. To protect equally all groups, it would be necessary to use the level required for those dolphin groups characterized by the "messiest" data.

Chartering a Fishing Fleet: Is It a Worthwhile Assessment Strategy?

Pierre Kleiber has ported to a SUN workstation the Tuna Observer Programme Simulator (TOPS), which he and Elizabeth Edwards developed. The TOPS model was created for the purpose of investigating biasing factors in the estimation of dolphin abundance from data collected by observers on tuna vessels. The model simulates a 1200 by 1200 nautical mile patch of pelagic ocean containing up to several thousand dolphin schools that move in response to an underlying environmental quality topography. The model can be adjusted so that dolphins aggregate to a greater or lesser degree on peaks of high environmental quality. The model also contains up to 100 fishing vessels that respond to dolphin encounters in such a way that the vessels tend to aggregate in areas of high dolphin density.

The new version of the model is designed to evaluate a recent proposal to charter the entire U.S. tuna purse-seine fleet for a short period of one or two days to gather data on dolphin abundance. During the charter time each vessel in the fleet would stop normal fishing activities and just count dolphin schools while steaming along a given transect line. It was hoped that this would be a less biased sampling scheme than that of data collected during fishing, when the vessels tend to concentrate on areas of high dolphin density and avoid areas of low density, thereby tending to over-estimate the abundance.

Using the new version of TOPS, Kleiber and Edwards have been simulating several fleet-charter scenarios, varying the degree to which dolphins are aggregated, the number of aggregations, and the terms of the charter. In these runs of the model, 30 fishing vessels are introduced at random positions at time zero. Prior to the charter period, these vessels spend 600 hours conducting normal fishing activities, searching for schools and stopping for 5 hours whenever a school is encountered. At

the beginning of the charter period, each vessel is assigned a random direction, and starting from its current position, it steams on this course for 24 hours simply counting dolphin schools. Abundance estimates based on numbers of schools sighted and track miles accumulated by 30 vessels are calculated for each 10 hours of the normal fishing period and for the first and second 12 hours of the charter period.

Six replicate runs of the model with no aggregation of dolphins were conducted to check that the new version of the model was behaving correctly. The actual dolphin abundance in the model was 2500 schools, and as expected, the estimates, though scattered, tended to agree with that number, both during the fishing period and during the charter period.

With dolphins aggregated, the results are very different. When fishing vessels are introduced at random positions, they first tend to underestimate the true dolphin abundance, but as the vessels aggregate on patches of high density during the normal fishing period, the estimates climb above the true value. The results from the charter period are highly variable, depending on the details of the charter arrangement and on the number and tightness of dolphin aggregations. In all cases tested, the data collected during the first 12 hours of charter greatly over-estimated the dolphin abundance, and the data collected during the second 12 hours yielded much lower estimates, underestimates in some cases.

The over-estimation results from a disparity in sampling intensity between regions of high and low dolphin density, high density regions being over-sampled and low density regions being under-sampled. Whether in normal fishing mode or charter mode, the sampling intensity depends on the number of track miles accumulated in each type of region, not on the number of vessels. During normal fishing the vessels tend to congregate in high density regions, but they are impeded in their accumulation of track miles by delaying to process each school encountered. Therefore there are fewer track miles sampled per vessel in high density regions than in low density regions. During the charter period, however, the vessels are not delayed by sighting schools. They accumulate track miles at the same rate as vessels in low density regions. As a result, until the vessels steam out of the high density

regions, the disparity in sampling intensity can be larger in charter mode than in normal fishing mode.

The shift in the distribution of track miles explains why in some cases, the abundance estimates from the first 12 hours of the charter period are biased to even higher levels than the normal fishing period estimates. These estimates correspond to a case where the charter period begins at dawn, giving approximately 12 hours of daylight for sighting at the start. On the other hand, if the charter were to start at dusk and the vessels were to steam all night along their tracks, the results would correspond more to the model results from the second 12 hours. In all cases except the no-aggregation case, the estimates from the second 12 hours were considerably lower than from the first. In some cases they were biased in the opposite direction. This is because in the second 12 hours, most of the vessels have steamed out the patches of high density, and most of their track miles in this time are in regions of low dolphin density.

It would be easy to simulate many more possible scenarios, but it is quite apparent from these preliminary results that the notion of chartering the fleet does not hold much promise in reducing the bias inherent in dolphin abundance estimates from tuna vessel observer data.

Monitoring Trends in Dolphin Abundance in the Eastern Tropical Pacific Using Research Vessels Over a Long Sampling Period: Analyses of First Three Years

In 1986, the NMFS initiated a long-term (6 years) research program to monitor relative abundance of dolphin populations in the eastern tropical Pacific (ETP). The program annually utilizes two research vessels for 120 days each. The research design should enable us to detect a 10% annual rate of decrease in northern offshore spotted dolphins (a total

41% decrease over six surveys) with alpha and beta error levels of 10%. Annual relative abundance estimates for 1986, 1987 and 1988 have been calculated for numerous species encountered, but emphasis is placed on those stocks most impacted by the tuna fishery (northern offshore spotted, eastern spinner and all stocks of common dolphins). Tim Gerrodette is the chief scientist in charge of these surveys.

Abundance estimates for the study area can be calculated in two ways. Components may be calculated by regions (roughly defined by dolphin density and searching effort) within the study area and abundances summed over regions, or data may be pooled over all regions to calculate components and estimates. The former is biased due to small sample sets; however, it takes into account regional differences in components (i.e., density and school size vary significantly among regions). Conversely, the pooled calculation is biased because it distorts the impact of regional differences; however, it utilizes larger samples. To date, estimates calculated using the pooled data method are more precise and appear to provide the most consistent estimates among years. The bias attributed to coverage appears to be acceptable because the percentages of survey effort in the regions have remained relatively constant among years.

Further investigations of the effects of stratifying by regions will be completed when the aerial school size analyses are complete. We will also investigate several factors which may have contributed to differences observed between surveys. Estimates will also be examined for evidence of a trend; however, trend conclusions at this date are premature (survey design requires at least six consecutive estimates).

Tuna/Dolphin Data Bases Updated

Data collected in 1988 by NMFS technicians (observers) aboard U.S. tuna purse seiners fishing in the eastern tropical Pacific Ocean have been edited by Biological Technicians Randy Rasmussen and Mike Trianni and placed into the tuna/dolphin database. This database contains information used to investigate the distribution, abundance, mortality and life history of the dolphin stocks involved in the eastern Pacific yellowfin tuna fishery.

In 1988, NMFS observers were on board for 31 of the 60 U.S. fishing trips and observed a total of 847 sets on dolphins. Observers counted a total of 3,373 dolphins killed in these sets for a dolphin kill per set rate of 4.00 animals and a kill per ton of tuna rate of 0.23. These rates are slightly higher than those observed in 1987 of 3.00 animals per set and 0.18 animals per ton.

Summary of 1987 Tuna/Porpoise Observer Data Published

Dolphin mortality rates in 1987, as measured by dolphin kill-per-set and kill-per-ton of yellowfin tuna caught, were down considerably from 1986 levels, according to data collected by observers aboard US tuna purse seiners and summarized by Biological Technician Al Jackson in NOAA Technical Memorandum "Summary of the 1987 US tuna/porpoise observer data" (NOAA-TM-NMFS-SWFC-136) issued in October. In 1987, an average of 3.11 dolphins was killed in each dolphin set and an average of 0.18 dolphins was killed per short ton of yellowfin tuna caught in these sets. In 1986, the dolphin kill-per-set and kill-per-ton rates stood much higher at 7.21 and 0.29. When examined on a yearly basis since 1981, there appears to be a trend toward a lower kill-per-ton rate, but no such trend is apparent for the kill-per-set rate.

A total of 13,382 dolphins was killed by the observed US fleet in 1987. Of this, 13,345 were killed in intentional dolphin sets and 37 in accidental dolphin sets. The dolphin population sustaining the most mortalities was the offshore spotted dolphin (8,436 mortalities), followed by the eastern spinner dolphin (2,557), the whitebelly spinner dolphin (981) and the common dolphin (882).

Of the 4,294 observed intentional dolphin sets, 2,659 sets (or 61.9% of the total) resulted in no dolphin kills, and 184 (4.3% of the total) were sets in which more than 15 dolphins were killed, often referred to as "problem sets". This compares favorably to 1981-86 when

no-kill sets accounted for 59.8% of the total, and problem sets accounted for 6.1%. The greatest number of dolphins killed in a single set in 1987 was 419 (211 offshore spotted and 208 eastern spinner dolphins). The relative frequencies of numbers of dolphins killed per set were quite similar for the three most heavily targeted populations: offshore spotted, eastern spinner and whitebelly spinner dolphins. However, for the less-frequently targeted and differently-behaving common dolphin, higher kill sets occur much more frequently, with problem sets accounting for 41.7% of the total.

Geographically, areas of high dolphin kill-per-set and kill-per-ton tended to be located along the southern periphery of the general fishing area, an area that traditionally is not heavily fished, and off Baja California. This situation is consistent with those of previous years. The dolphin most often involved in problem sets along the southern periphery was the offshore spotted dolphin; the problem sets off Baja California involved the common dolphin, exclusively.

Dolphin Stock Assessment Cruises for 1989 Completed

The NOAA Ships *David Starr Jordan* and *McArthur* departed San Diego on July 29 to conduct research in the eastern tropical Pacific Ocean. The *Jordan* was equipped with a Hughes 500D helicopter. The primary objective of the survey was to collect information to estimate the density, size, and species composition of dolphin schools in the eastern tropical Pacific (ETP) Ocean. Of special interest are the spotted, spinner, common, striped, and Fraser's dolphin. Populations of these five species, herein grouped and termed target species, are impacted by tuna purse seining in the ETP. The second objective was to collect information to investigate the physical and biological environment of the dolphin schools sighted. The vessels returned to San Diego December 7. Results presented here include preliminary summaries of data describing cetacean sightings during the survey.

The vessels surveyed predetermined tracklines during the 4 month survey. The tracklines are designed for line transect applications, and distribution of effort between regions was calculated using density estimates from earlier surveys. The *David Starr Jor-*

dan and *McArthur* surveyed 18,196 nm and 20,488 nm, respectively, in the study area. Within the study area, 38% of the effort was in the inshore region, 28% middle, 15% west, and 19% in the southern regions, respectively.

The cetacean survey was conducted by maintaining a visual watch using two 25-power binoculars mounted on the port and starboard sides of the flying bridge of each vessel. Binoculars were mounted on pedestals at a height of 10 m above the water, giving a maximum ship-to-horizon sighting distance of approximately 10 km. Daily watch for marine mammals was maintained during daylight hours (approximately 0600 to 1800 hrs local). Watch was stood by two teams of three observers on each vessel (six observers per vessel), with teams rotating every 2 hours.

On sighting a marine mammal school, information describing the sighting was recorded (e.g., time and position of the vessel, sighting cue, bearing and distance to the cue, and values of environmental parameters at the time of sighting). The bearing from the vessel to the sighted school was read from an azimuth ring on the binocular mount. Distance to the sighted school was recorded as a reticle distance read from a reticle mounted in the binocular eyepiece. When necessary for species identification confirmation, 35 mm photographs of the school were taken and noted in a log. Simultaneously, the CAST (Computer Assisted Sighting Technology) system continuously recorded bearing information. Data collected from the CAST system on this and previous cruises will be analyzed for reliability in estimating distance between the trackline and a sighted school of dolphins.

Preliminary calculations indicate that 1,418 schools of marine mammals were sighted. Forty percent of all schools sighted (569 schools) contained target dolphins.

For the third year, aerial photographs were taken during surveys to calibrate observers' estimates of dolphin school size. Typically it is very difficult to estimate the size of dolphin

schools from a ship, especially when some schools include several thousand individuals. It is not known whether dolphin observers are making large, systematic errors when estimating dolphin school size. To resolve the question of bias, a helicopter and an aerial photography program were incorporated into the design of the dolphin surveys. The helicopter operates from a specially-constructed platform on the *Jordan*. Two high-resolution aerial reconnaissance cameras are mounted below the helicopter fuselage. Large-format photographs are taken of dolphin schools. From these photographs an estimate of the actual number of dolphins in a school can be counted, and individual observer estimates can be calibrated against the more precise photo estimates.

Five members of the SWFC photogrammetry program participated in the 1989 survey. Team members included Andrew Dizon, Morgan Lynn, James Gilpatrick, Mark Lowry, and Robin Westlake. In addition to two photogrammetrists being present on each leg, the team consisted of a pilot and a helicopter mechanic, both provided by the NOAA Aircraft Operations Center.

The helicopter flew a total of 128.2 hours (11.1 of those hours consisted of pinniped, bird, and maintenance flights) during the survey. A total of 41 days was spent photographing small cetaceans and whales, averaging 2.9 hours per day. Seventy-six small cetacean schools and 10 whales were photographed from the helicopter. Researchers in the photogrammetry program are currently examining all photographs taken during the 1989 survey and are deciding which are of adequate quality to estimate school size.

Life History Parameters of ETP Dolphin Species Examined as Potential Indices of Population Condition

In a continuing effort to correlate biological parameters with the growth or decline of a population, the Biology Assessment Program has examined data collected from four eastern tropical Pacific (ETP) dolphin species. The four species are the spotted dolphin, spinner dolphin, common dolphin, and streaker dolphin. Each of these species is incidentally killed in the

yellowfin tuna purse-seine fishery but at different rates. Available population size indices for the offshore stock of spotted dolphin and two stocks of spinner dolphins (the eastern spinner and the northern whitebelly spinner) indicate that a significant decline in number has occurred since the fishery began in 1959. Comparable estimates for the common dolphin and the streaker dolphin populations indicate much lower rates of exploitation.

The survival and fecundity rates for each of these four ETP dolphin species are expected to have changed as their numbers declined. Although for long-lived mammalian populations, survival rates for the young-of-the-year and juveniles are predicted to exhibit change in a declining population before reproductive rates, survival rates are not directly measurable for ETP dolphin species. Thus, the potential for utilizing measurable life history parameters to predict population condition for these species is likely to be limited to the examination of reproductive rates.

To date we have analyzed the fractions of mature females that are pregnant, lactating, simultaneously pregnant and lactating, and resting. In addition to calculating these fractions for each of the species and the two stocks of spinner dolphins, the data collected since 1974 were analyzed for statistically significant temporal trends.

Although the fraction of mature females in each reproductive state is not directly comparable among the species, there are similarities and differences which may correlate to their relative degree of exploitation. The proportion of mature females that were pregnant in each stock and species was not significantly different; however, the proportion of mature females that were either lactating, simultaneously pregnant and lactating, or resting was significantly different. While the interpretation of differences in the proportion of the population that is lactating or resting is difficult, the simultaneously pregnant and lactating reproductive condition is proposed in the literature as a good indicator of changes in

population size relative to carrying capacity. For example, the percent of mature females that are simultaneously pregnant and lactating is thought to increase as a population moves away from its carrying capacity. Currently, we are testing for trends in this pattern that we can correlate with trends in relative abundance.

The most heavily exploited stocks, the northern offshore spotted dolphin, the eastern spinner dolphin, and the northern whitebelly spinner dolphin, exhibit the lowest proportion of mature females simultaneously pregnant and lactating. These proportions are lower than might be expected for stocks estimated to be below carrying capacity.

Examination of the available data for temporal trends has revealed that the proportion of simultaneously pregnant and lactating and resting females has significantly increased for common dolphins since 1974. For the spotted and spinner stocks examined, a statistically significant decreasing trend in the proportion of mature females present in the population was found, but there were no temporal trends by reproductive condition. Insufficient data are available to analyze temporal trends for streaker dolphins. Further analyses are being conducted to determine the effects of geographic location and season.

Eastern Tropical Pacific Cetacean Habitat Studies: Species Distributions and Habitat Variability

Patterns of intra- and interannual variability in cetacean distribution are currently being examined in relation to environmental variability, as part of the 6 year study monitoring trends in abundance of eastern tropical Pacific (ETP) dolphin populations affected by the tuna purse-seine fishery. Steve Reilly, fishery biologist, and Paul Fiedler, physical oceanographer, are monitoring the physical and biological environment as part of the program to interpret distribution changes, and ultimately help interpret apparent changes in cetacean abundance.

The ETP supports a diverse and abundant cetacean fauna, including plankton, cephalopod and fish consumers. Geographic distributions and multivariate statistical analyses indicate at least two basic patterns

of cetacean habitat in the ETP. The first pattern (e.g. spotted and spinner dolphins) includes warm, oligotrophic tropical surface water over thermocline depths intermediate for the region. The second pattern (e.g. common dolphins, pilot whales, *Globicephala macrorhyncha*, and blue whales, *Balaenoptera musculus*) includes cool and productive upwelling-modified water along the equator, coastal shelves and near the Costa Rica Dome.

Interannual changes were observed in the distribution of common, spotted and spinner dolphins during 1986-1988. During El Niño 1987 (with warm SST and unusually deep thermocline and low chlorophyll concentrations in equatorial waters), common dolphins contracted their range to the east of 90°W, and spotted dolphins were unusually abundant along the equator. During El Niño 1988 (with low SST and shallow thermocline along the equator and in tropical waters east of about 95°W), common dolphins were observed along the equator to 110°W, while spotted dolphins were relatively less abundant near the equator and in the easternmost part of the region north of the equator. The interannual changes in the environment were larger in absolute magnitude during 1986-1988 than they were before, during and after the "great" 1982-1983 El Niño. Consequently, it is believed that the interannual changes in dolphin distribution during 1986-1988 were among the most extreme interannual changes that occur in response to climatic variability.

Studies and Workshop on Effects of Seal Bombs Used in the Yellowfin Tuna Purse Seine Fishery Completed

An amendment to the Marine Mammal Protection Act in 1988 directed the Secretary of Commerce to complete a study on the effects of "seal bombs" on dolphins and to prohibit or restrict their use by April 1, 1990, unless it was determined that the "use of such devices do not result in physical impairment

or increased mortality of marine mammals." About half of the domestic fishermen fishing yellowfin tuna associated with dolphin use "seal bombs" to herd dolphin either to allow the vessel to encircle tuna in the purse seine or to assist in removing dolphin from the net during backdown. Other forms of "seal bombs" are also used by foreign fleets. In response to the MMPA requirement, SWFC Wildlife Biologist, Al Myrick, has been exploring different avenues of inquiry into the effects of seal bombs on dolphins. One of these involved conducting open-water tests of seal bombs on inanimate objects and on dolphin carcasses to determine whether mechanical damage could be done to the targets by underwater seal-bomb explosions. Another study involved the monitoring of set log data for years 1986-1989 to determine percent use of seal bombs on dolphins, and to estimate annual numbers of dolphins potentially exposed to bombs. A third study, involved examining inner ear tissue of purse-seined dolphin carcasses for evidence of hearing damage.

Since July 1989, tests have been conducted at sea using both the legal, Class-C seal bombs and illegal foreign-made bombs (over 40 grains of explosive). Using an electric detonator, the bombs were exploded remotely on target objects. Gelatin-filled bottles containing air-filled balloons and water- and air- filled metal cylinders were used as targets to simulate organ systems, and dolphin carcasses were used to simulate whole live animals. With considerable assistance from Chuck Oliver and the SWFC dive team, targets were deployed at various depths and distances from the detonation site and fired on. After the tests, the targets were examined for damage.

On November 27-29, 1989, a workshop was held in La Jolla, CA to determine whether the use of seal-control devices (SCD) results in physical impairment or increased mortality to dolphins that are chased and herded in the pursuit of yellowfin tuna by purse-seiners in the eastern tropical Pacific (ETP). Twenty-four people representing industry, the environmental community, and specialized fields participated in the workshop. Workshop participants concluded that physical injuries to dolphins were caused by Class C explosives when they were detonated within 0.5 meters of an animal. Data were not available to determine any damage to dolphin hearing, but the panel expressed concern about the long term or chronic

effects of "seal bomb" use on hearing which is considered critical to dolphin survivability.

An interim final rule to prohibit the use of explosive devices in tuna purse seine fishing operations that involve marine mammals took effect April 1, 1990, with a 30-day comment period. Foreign tuna harvesting nations must also prohibit the use of explosives in purse seine sets involving marine mammals within 180 days or face a ban on U.S. imports of their tuna.

Impacts of Changes in Dolphin Data Gathering Requirements are Examined

Beginning in 1987, the instructions for the collection of life history data by tuna vessel observers were revised. Life history data, including data on species, sex, total body length and reproductive conditions of females, are collected from individual dolphins. Both the National Marine Fisheries Service and the Inter-American Tropical Tuna Commission place biological technicians as observer on tuna purse-seine vessels in the eastern tropical Pacific to record the number and species of dolphins killed incidental to the fishery. Prior to 1987, life history data were collected from all sets. Subsequently, the instructions were amended to request that life history data be collected only if the total observed kill for a set exceeded six animals.

The change in criteria for collection of life history specimens was designed to correct for an observed collection bias in the sampling of female specimens. The collection of specimens from sets in which the kill was small, six or fewer animals, appears to include a preponderance of sexually mature females. Priscilla Akin and Susan Chivers, fishery biologists, are analyzing the life history data collected before and after this change to determine whether the estimation of reproductive parameters has been affected.

Reproductive data for all dolphin stocks with sufficient data available will be analyzed

to determine the effect of stratifying the data by the number of animals killed in a set. The data will be analyzed as the percent of females that are mature and the percent of mature females that are pregnant, lactating and resting. Preliminary results for the northern offshore stock of spotted dolphins show significantly fewer sexually mature females in sets with more than six dolphins killed, as expected, but no statistical difference in the representation of females by reproductive state (i.e., pregnant, lactating and resting). The representation of mature females in the life history sample before and after the 1987 change in observer instructions is unchanged in sets with more than six dolphins killed. These results suggest that this change in the criteria for the collection of life history data by observers has not introduced a bias. Analyses are proposed to further examine this question, including whether representation of juveniles and the length frequency of dolphins sampled has changed.

Research Plan Integrates Division Studies of Population Regulation in Eastern Tropical Pacific Dolphins

Staff members of the Fishery-Marine Mammal Interactions Division (FMMID) have just completed a document describing research for biological studies within the FMMID and how that research is to be integrated with ongoing surveys of trends in population abundance of dolphins in the eastern tropical Pacific (ETP) as well as environmental studies of the region.

National Marine Fisheries Service (NMFS) and Inter-American Tropical Tuna Commission (IATTC) tuna purse-seine vessel observer programs were established, in part, to collect data to make estimates of population size, mortality, and reproductive rates for assessing the impact of the kill by the international purse-seine fleet. The 1984 re-authorization of the Marine Mammal Protection Act (MMPA) relaxed the requirement to determine degree of depletion relative to the optimal sustainable population, and replaced it with an alternate approach for determining status of stocks of ETP dolphin. Rather than estimating absolute abundance, trends in the relative population size will be used to assess status of stocks. This, along with information about carrying capacity (k) and population

condition provides the necessary data to ascertain the influence, if any, of the fishing fleet on the stocks.

Information about population abundance and condition, as well as carrying capacity, should interact in a predictable manner. A matrix of theoretical interactions of a population demonstrating density-dependent responses while being harvested is described in the document. For instance, with the assumption of a stable carrying capacity, trends in population condition could be used to track trends in relative population abundance. Simultaneously determining trends in both population condition (K -indices) and size (P -indices) should allow prediction of changes in carrying capacity (k). Simultaneously examining trends in all three allows conclusions to be drawn regarding the effects of harvest.

P -indices are those related to changes in the absolute number of animals. Currently, the Southwest Fisheries Center is conducting a 6-year encounter rate survey of the ETP using two research vessels for 120 days each. Measures of relative population size form line-transect analyses of encounter rates of both research (and tuna vessels) in the ETP are clearly P -indices.

As part of the 6-year surveys of the ETP, extensive environmental measurements are being made. These studies, in part, are designed to provide information of trends in and influences on k of changes in the ETP environment. For example, trends in the average surface chlorophyll level can be used to infer trends in primary production in the study area.

K -indices are indices that relate the average condition of an animal in a population at the current density to the average condition of animals at equilibrium density. For instance, a negative trend in a K -index means that the average condition of an animal in the population is worsening. The NMFS and IATTC have maintained programs to collect biological data on ETP dolphin species for about 20

years. A variety of biological parameters that theoretically reflect the condition of animals in the populations are thus K-indices.

Life history parameters (K-indices) that respond to changes in density have yet to be identified for ETP dolphins. Simulation modeling will be employed to predict temporal trends in a variety of life history parameters and to investigate the effects of collection bias and harvest. The role of stress will also be investigated as it may be a factor influencing the ability of depleted populations to make density-dependent responses.

If, after the 6-year survey period, trends in the identified K- indices and P-indices are consistent with what we know about the ETP environment (i.e., k), confidence in any recommendations regarding status of stocks and harvest stemming from the research described here will be materially enhanced. The report is available as an Administrative Report LJ-90-03.

VI. MISCELLANEOUS

Computer Graphics for Evaluation of the Pacific Tuna Fisheries Developed

The highly migratory tunas inhabit vast regions of the Pacific Ocean and they are exploited by different fisheries at different stages in their life cycles. Knowledge of their spatial distribution in relation to the large scale circulation patterns of the Pacific is a necessary prerequisite to any evaluation of the population dynamics of the various populations or any assessment of the fisheries which harvest them. This knowledge can be achieved by in-depth analysis of the large amount of Japanese and U.S. data available on the Pacific tunas; however, it is difficult to convey this information to those responsible for fisheries management or to the public.

In an attempt to make the mass of information available to a wider audience, Fishery Biologist Richard Parrish has developed a series of computer programs and computer graphics which display the Japanese and U.S. tuna catches, fishing effort, and catch rates. The original emphasis of this work was on the catch at size of albacore tuna in the North Pacific troll, baitboat and longline fisheries. However, multi-species aspects of the various fisheries are also being evaluated.

The Japanese longline fishery catches a wide range of tunas and billfishes; however, the fishery is dominated by catches of yellowfin, bigeye and albacore tunas. In the North Pacific the longline fishery primarily takes yellowfin tuna in the central and western Pacific between the equator and about 15°N; in the region of the Equatorial Counter Current and the North Pacific Equatorial Current. Bigeye tuna catches are also high in the Equatorial Counter Current and North Pacific Equatorial Current regions but they are concentrated further east than the yellowfin tuna catches. Bigeye tuna catches are also high along 30°N, east of Japan and to the northwest of Hawaii. Albacore catches are concentrated between 25-35°N in the region south of the North Pacific Current. Albacore

catches are at a minimum in the eastern tropical Pacific and in the California Current Extension.

Although there is considerable spatial separation of the catches of the three species, when viewed as a whole, it is apparent that the Japanese longline fishery occurs over nearly the entire tropical/subtropical North Pacific, from the equator to about 40°N. Catches are at a maximum from the equator to 15°N and along 30°N in the region south of the North Pacific Current; there is a minimum of catches along 20°N in the region of the central water mass and in the region of the California Current Extension. Japanese longline fishing effort has a pattern similar to that of the combined catch of the three tuna species; however, in comparison to catches there is a relative lack of effort along 30°N in the region north of Hawaii. Highest rates of the three species occur in the western equatorial region, just south of Japan and in the region to the north and east of Hawaii.

Fishing Industry Reviews Proposed Seafood Regulations

Fishery Biologist Raymond P. Clarke and Biological Technicians Donald R. Hawn, Russell Y. Ito, and Kurt E. Kawamoto attended a workshop on the Model Seafood Surveillance Project (MSSP), Hazard Analysis Critical Control Point (HACCP) as applied to Hawaii fishing vessels. The workshop was held at the Ilikai Hotel on October 20-21, 1989. Twenty-three people from industry and 10 from government participated in the workshop.

The purpose of the workshop was to give consultants from NMFS information on the condition of Hawaii's fishing industry and to review the proposed nationwide standards as they would apply in Hawaii. The MSSP is designed to improve seafood quality in the United States, protect the consumer from harmful seafood products, and keep up with international competition for producing high

quality seafoods, as in Europe and Canada. The workshop is one step in the application of a HACCP procedure under the new U.S. seafood inspection law. The MSSP proposes to monitor critical points in seafood operations--the critical points being harvesting, processing, and transfer.

The workshop resulted in a preliminary set of recommendations that apply specific conditions from Hawaii's fishing fleet to the proposed standards. The need for further research was highlighted as well. A follow-up workshop will be held in February 1990, to summarize the industry's input into regulations on seafood quality, which would require certification of individual fishing vessels throughout the United States. It appears that actual implementation of new standards will not occur before 1992.

SWFC Scientists Attend FAO Planning Meeting

Drs. Pierre Kleiber and Norman Bartoo, SWFC, La Jolla, attended a planning meeting at the South Pacific Commission, New Caledonia, for the purpose of organizing an FAO-sponsored expert consultation on Pacific tunas and interactions between tuna fisheries. This expert consultation will include fishery scientists and fishery officers from various countries throughout the Pacific and beyond, and will be held in early 1991. Richard Shomura, retired Director of the SWFC Honolulu Laboratory, is the chairman.

The planning meeting was to establish a work plan for tasks that need completing for the consultation. Several working groups were established to review available data, conduct analyses, and prepare material for presentation at the consultation. The chairman of the working group will be contacting other scientists who may be interested in participating.

Bartoo is heading one of nine species working groups. His group will review the state of knowledge of North Pacific albacore in relation to fishery interaction questions. Where possible, the group will evaluate the significance of interactions between the various fleets that exploit that resource. Chairpersons for the other species working groups will be following this format.

Kleiber is in charge of a working group dealing with fishery interaction in general. This group will be in charge of developing and evaluating methodologies for assessing interaction and will help coordinate interaction assessments in the species working groups.

The exact time and place of the consultation has not yet been decided by FAO. However, Noumea, New Caledonia; Shimizu, Japan; and Manila, Philippines are among the locations being considered.

Brill Attends Two International Conferences

Fishery Biologist Richard W. Brill attended the Kjell Johansen Commemorative Symposium, Strategies of Physiological Adaptation, at the August Krogh Institute in Copenhagen, Denmark, July 6-8, 1989, and the XXXI Congress of Physiological Sciences in Helsinki, Finland, July 9-14, 1989. At the symposium in Denmark, Brill presented a poster, "Temperature effects on the acid/base balance of isolated whole blood and plasma of yellowfin tuna (*Thunnus albacares*)," which was coauthored with David Jones and Peter Bushnell, who are with the University of British Columbia.

The poster described a re-investigation of the unusual rates of pH change with temperature previously reported in isolated tuna blood. Tunas often subject themselves to rapid temperature changes during vertical movements, which are a regular part of their behavior. Also, because they have countercurrent, vascular heat exchangers, their muscle temperatures may be as much as 10°-15°C above ambient. Tuna blood is therefore regularly subjected to rapid temperature changes in open (i.e., in the gills) and closed systems (i.e., in the vascular heat exchangers). Understanding how tunas regulate their blood acid-base balance is therefore critical to understanding their habitat requirements and temperature tolerances.

The effects of temperature on the acid-base balance of the blood of skipjack tuna were first investigated in vitro by S. F. Perry and others, who found similar rates of pH change with temperature in open (i.e., constant pCO_2) and closed systems (-0.0131 and -0.0165 pH units/ $^{\circ}C$, respectively) (cf. Comp. Biochem. Physiol. 81A:49-53, 1985). These data contrast sharply with those for marine seatrout, *Cynoscion arenarius*, which have more typical rates of pH change with temperature (-0.0048 and -0.0150 pH units/ $^{\circ}C$ in open and closed systems, respectively) according to a study by J. N. Cameron (Respir. Physiol. 33:129-144, 1978). Perry and others postulated that the unusual rates of pH change with temperature in tuna blood were an adaptation related to the unusual anatomy, physiology, and lifestyle of these pelagic teleosts. Blood from albacore also exhibits a high rate of pH change with temperature (0.016 pH units/ $^{\circ}C$) in the open system, according to a study by J. J. Cech and others (J. Exp. Biol. 109:21-34, 1985).

The study described in the poster used blood from small (ca. 1-3 kg) yellowfin tuna, equilibrated at temperatures inhabited by this species and at CO_2 levels corresponding to normal arterial and venous blood values. Results showed that the yellowfin tuna blood had an unusually high HCO_3 and non-bicarbonate buffering capacity when compared with other teleosts. Tuna blood and plasma had the same rates of pH/ $^{\circ}C$ and pCO_2 / $^{\circ}C$ in a closed system as other teleosts; this result was expected since these changes were most likely due to reciprocal titration of plasma proteins and HCO_3 . Tuna red blood cells appeared to be involved in the unusually high pH/ $^{\circ}C$ and $[HCO_3]$ / $^{\circ}C$ changes occurring in the open system. The pH/ $^{\circ}C$ changes in the open system were pCO_2 dependent and independent of $[HCO_3]$ / $^{\circ}C$ changes, most likely reflecting the movement of strong ions into or out of red blood cells. The study is part of a larger effort aimed at understanding the in vivo regulation of acid-base status in tunas.

At the symposium in Finland, Brill presented an invited lecture, "Comparative physiology of animal athletes: Tunas and other fast fishes." His lecture centered on the new concept that the unique anatomy, physiology, and biochemistry of tunas have evolved not to permit exceptionally high sustained swimming speeds, but rather to permit rapid repayment (i.e., rapid lactate metabolism) of the exceptionally large oxygen

debts (i.e., high muscle lactate levels) that tunas are capable of accumulating. Previously, tunas were assumed to be like human athletes: good marathoners. Brill pointed out that these terms are inappropriate despite the title of the lecture, because the unique environment in which tunas live does not lend itself to description by analogy to situations in the terrestrial environment. Brill's lecture was part of a symposium on the physiology and biochemistry of elite animal athletes.

Tuna Vessel Observers Start Collecting Turtle Data

Starting this year, observers on tuna purse seine vessels will be collecting data on turtles that are observed at sea or come aboard during fishing operations. This program will allow the SWFC to monitor fishery interactions with sea turtles in the pelagic waters of the eastern Pacific, as well as substantially augment our meager understanding of turtle ecology on the open ocean.

Studies on Species Associated with Yellowfin Tuna in the Eastern Tropical Pacific

Before 1976, U.S. porpoise observers recorded species of large animals that co-occurred in tuna sets made by purse seiners in the eastern tropical Pacific. The fishery targets on free-swimming schools of tuna, and tuna associated with floating logs and porpoise schools. Although the data are not collected in a uniform way, sufficient information is available to allow characterization of the allospecies associates of yellowfin tuna in log, school, and porpoise sets. Fishery Biologist David Au recently completed a review of the data and an analysis of associated species. A total of 1,762 tuna set records collected during 1974 and 1975 was reviewed. Sharks were the most common in association with tuna, co-occurring in up to 90% of log sets. The overall average for log sets was 40%, representing mainly silky

sharks, and 10% in porpoise sets of mainly whitetips. Most other nektonic animals associated with tuna schools averaged in the 10% or less range. These include manta rays in log and school sets, billfish in all set types, turtles, and bullet and black skipjack tunas in some sets, especially in log sets. Dolphin fish (mahimahi) were relatively common in log sets at 24%.

Most sets, especially porpoise sets, were also associated with birds: boobies, shearwaters, terns, and frigatebirds. A significant number of school sets was associated with shearwaters and terns, and a significant number of porpoise sets was sighted with boobies and frigatebirds. These results are consistent with the hypothesis that tunas increase their foraging speed in oligotrophic waters to maximize their prey encounter rate and hence, are associated with the faster sea birds, shearwaters and terns. A manuscript has been prepared describing these associations in terms of behavior within communities. A companion paper on the avifaunal characteristics of "log", "school", and "porpoise" associated schools of tuna in the eastern tropical Pacific was also prepared. Some 1,762 catch records, which were obtained by observers during 1974 and 1975 when much information on species associated with tuna catches was collected, were analyzed. Terns and small shearwaters were most abundant with schoolfish tuna, while boobies, frigatebirds, and the larger shearwaters were more abundant with logs, and especially porpoise-associated tuna. This difference was observed in the occurrence rates of the bird species, and in the flock sizes by species and flock characteristics. It is hypothesized that the avifaunal differences are related to species-specific, aerial foraging tactics used by the birds in pursuit of prey driven to the surface by tuna.

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MAY 1, 1989 to APRIL 30, 1990

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APPROVED BY SCIENCE AND RESEARCH DIRECTOR, SWR

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